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ABSTRACT

This document is the final report to develop a new elementary science curriculum. It contains information related only to the development phase of the Conceptually Oriented Program in Elementary Science (COPES) and was written for an audience that includes all who are interested in curriculum development as it was experienced in this project. The ultimate goal of the COPES program is to develop understanding of the nature of matter at various levels of sophistication. Five conceptual schemes were chosen for the curriculum: (1) The Structural Units of the Universe, (2) Interaction and Change, (3) The Conservation of Energy, (4) The Degradation of Energy, and (5) The Statistical View of Nature. These five conceptual schemes are interwoven in a logical hierarchy with all five being developed concurrently. Positioning of a concept within a particular scheme was determined on the following bases: its contribution as an introductory idea, its suitability for active exploration at a given age level, and its relative sophistication as a component of the scheme. The parts of the report are: Introduction, An Overview of COPES, the COPES Learning Activities and Assessments, Problems, Research Studies Dealing with COPES Materials, and The Future of COPES. (PES)

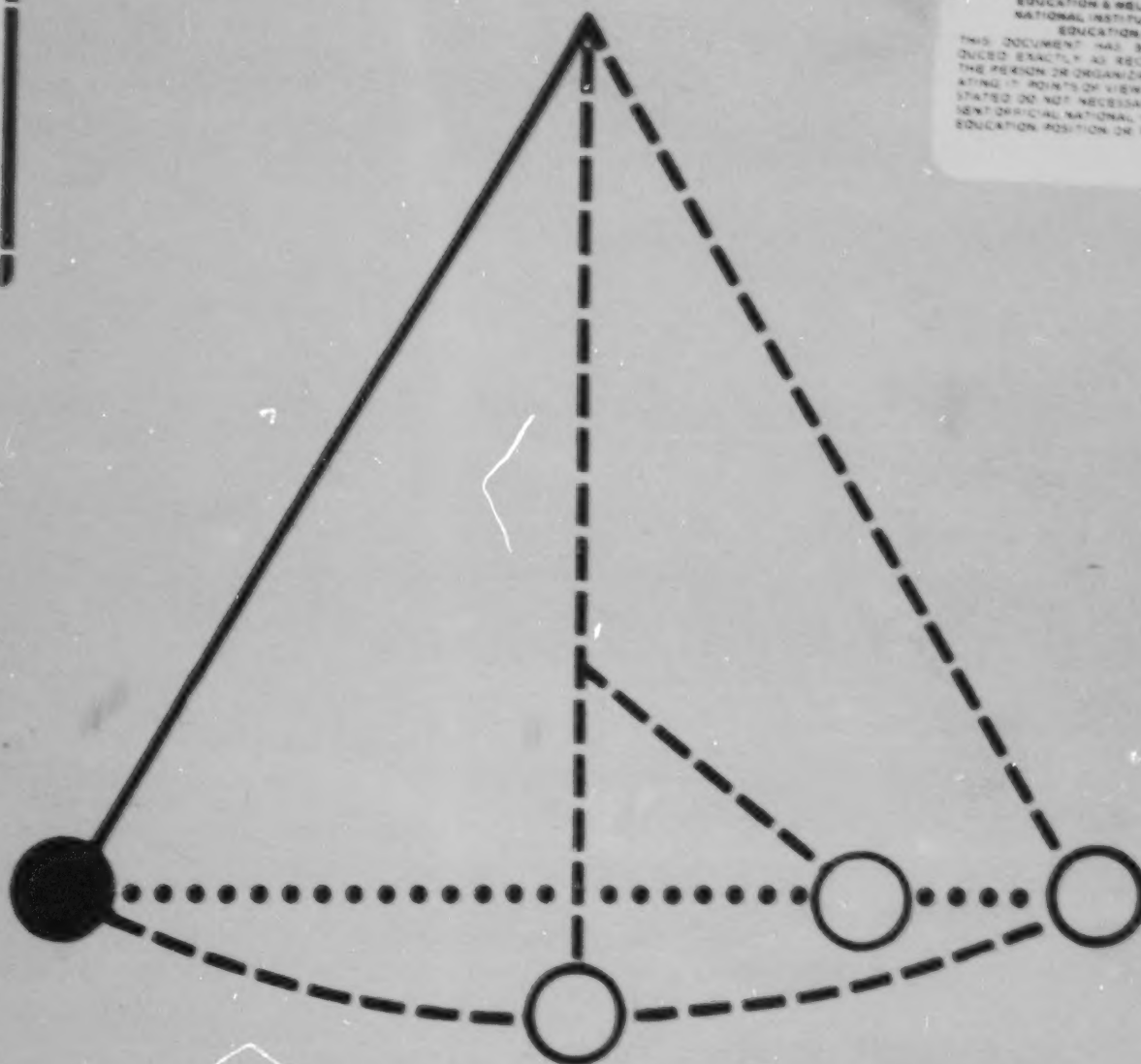
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COPES

Conceptually Oriented Program
in Elementary Science

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Final Report
September 1973

A Project To Develop a New
Elementary Science
Curriculum



New York University

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FINAL REPORT

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A PROJECT TO DEVELOP A NEW
ELEMENTARY SCIENCE CURRICULUM

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U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education

Bureau of Research

FOREWORD

The report that follows was initially requested by the Office of Education and covers only the Development Phase of COPES. The Pilot-Study Phase has been reported in a document submitted to the Office of Education in August, 1967. As was true of the report of the Pilot Study, this report is written for an audience that includes all who are interested in curriculum development as it was experienced in the COPES Project. We have attempted to be objective in reporting our experiences in accomplishing the monumental task of producing an entirely unique K-6 science curriculum. What we have recorded here should be helpful in understanding why the Development Phase of this Project has taken almost two years longer to complete than we had expected. The task of creating learning activities, the likes of which had never before been used in an elementary science curriculum, challenged the most innovative members of the COPES team. However, the major challenge was to select from among the activities, those that were most suitable, and to orchestrate those innovations into a series of sequences from Kindergarten through Grade 6 that would lead children to a progressively sophisticated understanding of the conceptual structure of science.

The primary product produced by the Project during its Development Phase has been preliminary editions of the COPES Teacher's Guides. Six such guides have been produced. However, in order to complete production of the Teacher's Guides for grades 5 and 6, supplemental funds had to be obtained from the National Science Foundation. Furthermore, the guides have been printed and are being distributed by the Center for Educational Research and School Services of the School of Education at New York University. Without this assistance, from the Foundation and from the Center, it is doubtful that the guides would have been as broadly distributed as they are today. It is estimated that one or more of the guides have found their ways into at least 1,000 elementary schools.

As the COPES Project was originally conceived, its final phase was to determine how the program could accomplish its mission under a variety of teaching conditions. Unfortunately, funds could not be obtained for such critical field testing. Although this record is referred to as a final report, actually it is not. The final report on COPES cannot be written until it has been practiced in elementary schools for a number of years and an effort has been made to determine whether or not it produces classes of children who have been intellectually challenged in ways that will sustain their interest in, and appreciation of science; outcomes which very few present science programs accomplish.

In those instances where teaching materials from COPES have been used by elementary school teachers their reactions have been highly favorable. To increase appreciably the number of COPES users the teacher's guides and related materials must be published and distributed commercially. We are hopeful that this may be undertaken within the next year and that COPES will thus begin to make the impact upon science teaching that it has been designed to produce.

Morris H. Shamos
Director of COPES
September, 1973

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INTRODUCTION

COPES is an acronym for Conceptually Oriented Program in Elementary Science. The COPES Project was sponsored by New York University and was conducted as an all-university effort with initial enabling grants from the United States Department of Health, Education, and Welfare through the Bureau of Research, of the Office of Education. Supplemental funds, to complete the teacher's guides were obtained from the National Science Foundation. These funds, along with funds advanced to the Project from the School of Education's Center for Educational Research and Field Service made it possible to complete the Project through its first two phases. Without funds from the latter two sources only four of the six COPES Teacher's Guides would have seen the light of day.

It was anticipated that there would be three phases to the COPES Project. The first, or Pilot Study Phase, was conducted to test, experimentally, the feasibility of a conceptual scheme approach in developing a curriculum for elementary science. Conservation of Energy was the conceptual scheme selected for the feasibility test. The second, or Development Phase, was contingent upon obtaining positive results from the Pilot Study. It was in the development phase that a complete elementary science curriculum, based upon a selected few conceptual schemes in science, was to be produced. The third, or Field Testing Phase, was to include a comprehensive evaluation of the COPES curriculum material in elementary schools associated with six selected test centers located in various parts of the United States. Since it was impossible to obtain the necessary funds from either federal agencies or commercial sources, the Field Testing Phase of COPES was not completed. This was indeed regrettable because it left the Project with perhaps its most critical phase unfinished. It was originally estimated that a comprehensive three-year field testing effort on a nationwide basis would have cost approximately \$1,500,000.

The COPES Pilot Study was conducted over a period of two years at a cost of \$169,402. The Development Phase, originally planned to be completed in about four years, has taken almost six years. The total cost for the Development Phase has been approximately \$970,165.* Of this amount \$811,165 was contributed by the Office of Education. In two supplemental grants, the National Science Foundation contributed a total of \$84,000. The remaining costs have been paid as advances, from the Center for Educational Research and Field Services, in anticipation of reimbursement from the sale of COPES Teacher's

*Includes University and local contributions amounting to approximately \$75,000.

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Guides which the Center has printed and is now distributing. Although the total cost of COPES, through the development phase, has been approximately \$1,138,567, this is a relatively small amount when compared with the expenditure of federal funds for other prominent elementary science programs, e.g., Science a Process Approach (SAPA) and Science Curriculum Improvement Study (SCIS).

Since the COPES Pilot Study has been officially reported in another document published in August, 1967¹, the present report will cover only the COPES Development Phase. In the report of the Pilot Study interested readers can obtain background dealing with the COPES rationale, its staff organization, personnel associated with the Pilot Study, its laboratory school, the methods by which supporting concepts for one conceptual scheme were identified, procedures for developing the teaching material along with the tests used in the Pilot Study, the purposes of the experimental testing as well as the manner in which it was conducted, results, and the recommendations that followed. The teaching materials for the Conservation of Energy Sequence that were used by teachers during testing in the schools were revised and published in 1967 as a limited printing by the Project. The cost of subsequent printings of The Teacher's Guide for A Conservation of Energy Sequence has been met through advances against anticipated reimbursement from sales of the guides by the Center for Field Research and School Services, School of Education, New York University. This guide was prepared in isolation from the other four schemes, however, the vertical K-6 development of the one scheme has generated sufficient interest to sell several thousand copies of it.

In this, report on the Development Phase of COPES, consideration will be given to the following:

1. An overview of COPES
2. The COPES learning activities and assessments
3. Problems encountered during the Development Phase
4. Research in which COPES materials have been investigated
5. The future of COPES

¹Morris H. Shamos and J. Darrell Barnard, A Pilot Project to Develop an Elementary Science Sequence, United States Office of Education Project No. H-281 (New York: New York University, 1967).

CHAPTER II

AN OVERVIEW OF COPES*

The Ultimate Goal

The ultimate goal of the COPES program is to develop an understanding of the nature of matter at various levels of sophistication. In the study of "the nature of matter" we include the entire breadth of science (both animate and inanimate)--an understanding of the structure of matter as well as its behavior.

We believe that having such a definite goal adds to the strength of a science curriculum, for it not only provides teachers and students with clearly defined objectives but also, perhaps more importantly, gives them a cohesive picture of science rather than a series of disjointed topics.

Each concept, each conceptual scheme in this approach, is presented in a structured learning sequence with the purpose of contributing to this understanding. The order of the sequence is in the form of a "spiral" development, in which at each succeeding level of sophistication, the students proceed from the most basic skills and concepts through the entire sequence as far as their maturity and learning capacity permit them to go in understanding the major conceptual schemes or those concepts necessary to this understanding.

The Conceptual Schemes

Which conceptual schemes--which of the "great ideas" in science--should form the core of a conceptually oriented program in elementary science? There is probably no single choice of schemes that would fully express the views of all scientists and science educators. The breadth of the fields of interest and of science itself probably would result in many similar but not identical lists. After reviewing the efforts of two NSTA curriculum committees² and following consultations with scientists and science educators, we selected five conceptual schemes

*This material has been taken from COPES, a descriptive brochure, printed by the Center for Educational Research and School Services, School of Education, New York University, November, 1972.

²Morris H. Shamos, "The role of Major Conceptual Schemes in Science Education," The Science Teacher, XXXIII, No. 1 (January 1966), 27-30. Theory Into Action in Science Curriculum Development (Washington, D.C.: The National Science Teachers Association, 1964).

around which the COPES curriculum has been developed. The selection was based both upon what the scientists felt would be a meaningful and durable science program and upon the successful development of a logical and rational hierarchy of concepts for the first conceptual scheme, Conservation of Energy--rational because its structure is based not only on the sequential growth of ideas but also on the abilities of children to think in terms of abstractions as well as of concrete situations, to do model building or to exercise the required manipulative or mathematical skills.

A limitation of the Pilot Study was the attempt to develop one conceptual scheme, Conservation of Energy, in isolation from others. This was obviously less than ideal since science cannot be so rigidly segmented. In the full program this was no longer a problem since five schemes are developed concurrently and suitably interwoven with one another.

Following are the five conceptual schemes on which the full COPES curriculum was based, with a brief description of each:

1. The Structural Units of the Universe

The notion that the universe is made up of various kinds of discrete units of matter is central to the formal pursuit of science. Whether these be the smallest subnuclear particles or the largest stars, whether a single living cell or a complex organism, it is the discreteness of matter that makes it feasible to study nature--to classify its structural units and establish a hierarchy among them. The structural units with which students have any direct experience, that is, large-scale matter, are composed of smaller units and these, in turn, of still smaller units. Atoms, molecules, crystals, cells, organisms, plants, animals, planets, stars, etc.--these are the structural forms in which matter is found. The more complex forms, or higher levels of organization, exhibit properties that are generally more than the simple sum of their parts. As for the fundamental "building blocks" of matter, for the purpose of the COPES program these are taken to be atoms or, as more commonly encountered in nature, molecules.

2. Interaction and Change

Taken as a whole, the universe is constantly changing. This is evident at most levels of organization: stars, planets, geological formations, living things, etc., all change with time in perceptible ways. Some changes are readily observable, which means that they occur in relatively short periods of time. Certain chemical and nuclear reactions are examples of rapid changes. Others, such as most evolutionary or geological changes, involving very long periods of time, are not as evident and must be inferred from indirect evidence rather than from direct observation. This, the rate at which a given change occurs is a critical factor in detecting this change and assessing its magnitude and import.

Changes occur because of interactions among the structural units of matter, with the result that either the properties or arrangement of the units may be altered. Interactions among units of matter take place through fields of force, of which several basically different types can be distinguished but only two of these, gravity and electromagnetism (electric and magnetic forces), are normally experienced by the average individual. In fact, the electric force alone is sufficient to account for most of our experiences, including practically all chemical and biological changes.

The weakest force (gravitational) and the strongest (nuclear) play particularly interesting roles in effecting changes in the universe. The former is significant only for the largest structural units (planets, stars, etc.), while the latter applies only to the smallest (subnuclear) particles.

3. The Conservation of Energy

As one contemplates the concept of a changing universe it is comforting to find some properties of the universe that appear to be invariant. Such invariant properties are said to be "conserved," and the statements describing them are generally referred to as the "conservation laws."

The most fundamental of these laws are conservation of electric charge and conservation of energy. The latter is of special interest because it is so basic to all of science, finding numerous examples in both the physical and biological sciences. On the other hand, conservation of matter, if thought of as conservation of mass, while a useful concept in ordinary (low-energy) phenomena, is not valid for high-energy interactions. Instead, the principle of Conservation of Energy has been broadened to include mass as a form of energy, leading to the conservation of matter-energy.

The notion that the total amount of matter and energy in the universe remains constant is obviously a powerful conceptual idea, perhaps the most useful guiding principle in all of science. The more limited idea of Conservation of Energy alone, while not so inclusive, is found to hold so well for the (low-energy) interactions normally encountered by students (e.g., in energy conversion) as to constitute a highly significant conceptual scheme at the level to which the COPES program is addressed.

4. The Degradation of Energy

Natural events tend to have a unidirectional character. That is, changes occur in such a way as to bring the universe closer to a final state in which it will have lost the ability to do any useful work. Thus in the conversion of energy from one form to another, while the principle of energy conservation applies, part of the energy appears in a form that cannot be fully harnessed to

do mechanical work. This form is heat energy, by which is meant the (kinetic) energy of the assumed random motion of particles of matter.

The idea of particles moving at random is central to the kinetic-molecular theory, which has proved to be such an effective model for understanding gases, as well as the concepts of heat and temperature and the states of matter. In this sense degradation of energy means that every change in the universe occurs in such a way as to result in greater randomness; that is, matter tends to spread out or become less organized and energy to distribute itself more widely.

In more formal terms, the idea that changes occur in this fashion is expressed as the second law of thermodynamics. Thus, heat flows from a warmer to a colder body, but the reverse is not observed unless energy is supplied from an external source. The same general idea applies to all changes, e.g., even to those in living systems, which appear to result in higher states of organization. While the organism itself may become more ordered, it does so only at the expense of its environment, which becomes more disordered, the net result being an overall trend toward disorder (increased entropy), meaning that the total energy is degraded.

One cannot fully develop the idea of energy conservation in a meaningful way without also calling attention to the direction of energy changes, as embodied in the corollary conceptual scheme, Degradation of Energy.

5. The Statistical View of Nature

The modern view is that natural events can be predicted only on a statistical basis. Most of our experiences with nature involve large numbers, with the result that on the whole nature appears regular and predictable. Even the smallest sample of matter with which one normally comes into contact contains huge numbers of atoms or molecules, so large that one can readily predict the average behavior of the sample. This is analagous to a game of chance, where given a large number of events the overall outcome can be reliably predicted, although the result of a single event cannot be forecast. In fact, the same mathematical laws of probability that apply to games of chance appear to be successful in helping one predict the statistical behavior of natural phenomena.

When one studies individual or small numbers of events, the random character of natural phenomena becomes evident. Radioactivity is one such phenomenon where behavior can be predicted only on a statistical basis. Another is the transmission of genetic characteristics to successive generations of living things, as described by the Mendelian laws. Still another is the Brownian motion of small (microscopic) particles. Examples are limited, since randomness is apparent only when

dealing with small numbers, which one does not often encounter in nature.

Yet the idea that on a submicroscopic level all phenomena are random, and that nature is predictable only by the play of large numbers, is obviously a basic and important conceptual scheme. The challenge is to convince students that one can reasonably generalize to this conclusion from the few concrete examples that are available.

The COPES Curriculum

The full COPES curriculum is a structured program containing all five of the conceptual schemes interwoven in a logical hierarchy. All five are developed concurrently. Positioning of a concept within a particular scheme was determined on the following bases: its contribution as an introductory idea, its suitability for active exploration at a given age level, and its relative sophistication as a component of the scheme.

The curriculum is presented in the form of a series of Teacher's Guides for kindergarten through the sixth grade. The Guide for each grade level includes several sets of teaching Activities. The individual Activities are presented in a two-column format. Suggestions for step-by-step teaching procedures, including questions that might be raised with the children, are presented in the left column; practical hints, explanations of the science content, and alternative teaching suggestions and explorations appear in the right column.

The K-2 Guides are devoted primarily to introductory materials. They contain sets of Activities that provide youngsters with the skills and the conceptual framework needed for entering the main sequences starting at Grade 3. The introductory concepts in the K-2 Guides are dealt with under such topics as: Interactions, Describing Objects, Measurements, and Variability. None of the topics is treated at one grade level only. Rather, increasingly sophisticated activities related to each topic are included in the sequence for each of these three years. For example, Melting is designed as a kindergarten Activity to build introductory concepts concerning the interaction of matter and heat energy. This is followed by the Activity, Adding and Removing Heat Energy from Substances, in the first grade and the Activity, Prediction and Temperature Change, in the second grade.

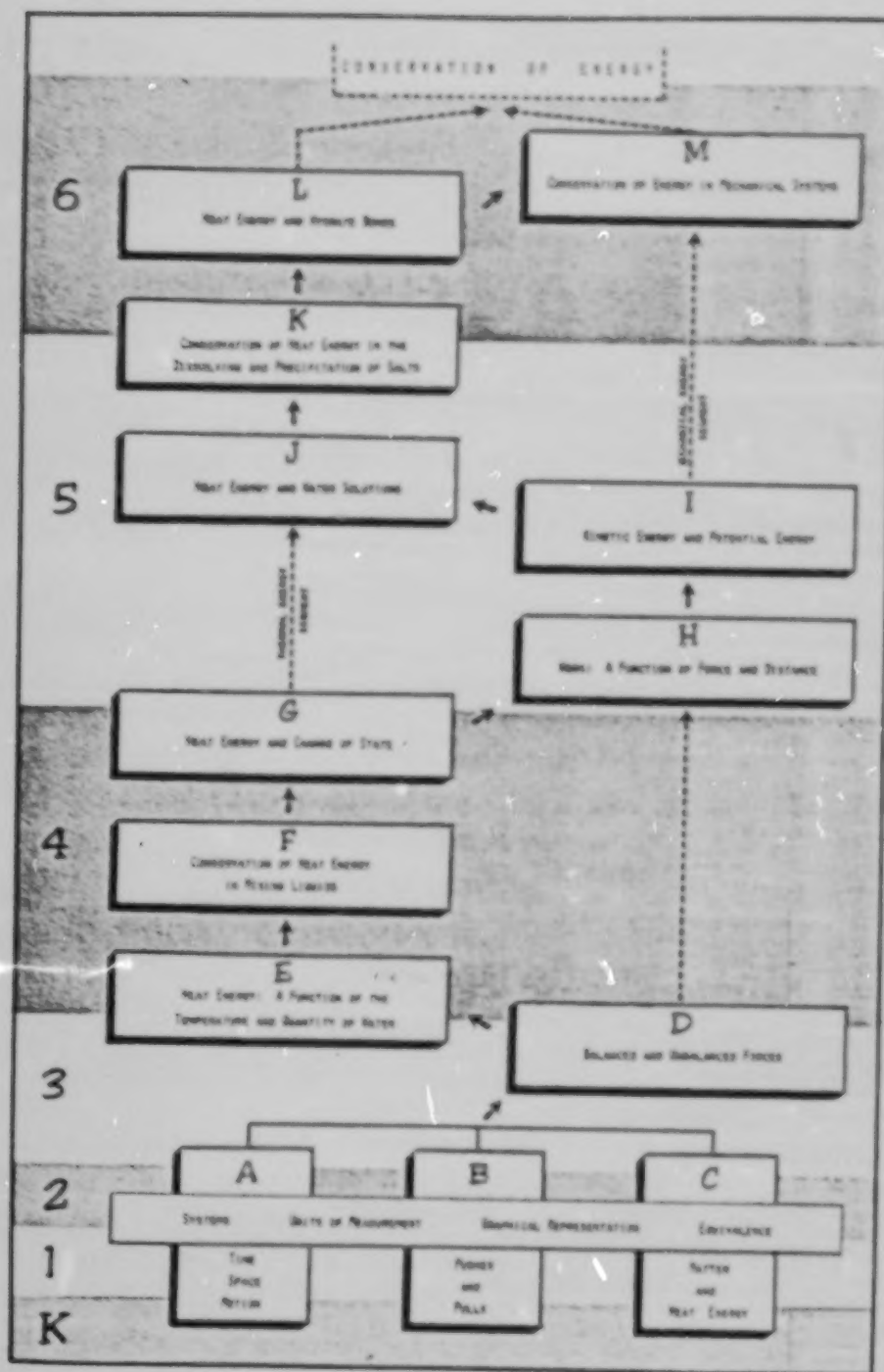
Those concepts intended to develop the five conceptual schemes are spread through grades 3-6. In some instances, a concept is related almost exclusively to a single conceptual scheme. As in the case of the sets of introductory concepts, no one scheme is designated for teaching at any

one grade level. Rather, it is anticipated that children will be learning concepts related to each of the five conceptual schemes in every one of the four upper grades. The Conservation of Energy pilot sequence as shown on page 9 illustrates the continuous sequential development of concepts related to one of the conceptual schemes, Conservation of Energy. In each Teacher's Guide for the upper grades, the Activities within a set are themselves arranged sequentially. Thus each set is referred to as a Minisquence within the main sequence for a particular conceptual scheme. Each of these Minisequences, to a greater or lesser extent, depends upon the preceding ones. Thus, within any one grade, the Minisequences are arranged sequentially, as are the Activities included within them.

COPES does not make an issue of the distinction between concepts and skills in the development of an Activity or Minisquence. Rather, we have tried to apply skills in the enhancement of concept learning and to introduce concepts as the focuses of skills. For example, the child learns the skill of grouping, or classification, concomitantly with the concept of a group as a set of objects having a common property. Also, the concept of property can be abstracted from observations of objects in groups, while at the same time the skill of making abstractions is being developed. Thus, an attempt to make a clear distinction between "grouping" as a skill and a "a group" as a concept--or between "property" as a concept and "seeing properties" as a simple kind of abstracting skill--seems more likely to confuse the child than to help him at this stage of his cognitive development. The trained scientist abstracts as he recognizes properties in complex phenomena, and classifies those phenomena into larger groups in terms of perceived properties, without introspecting about whether, at any particular moment, he or she is practicing a skill or applying a concept.

Assessment Materials

The Assessment materials have been designed to be an integral part of the teaching-learning process in COPES. The primary theme of the COPES curriculum is that experience, with the ideas underlying common phenomena, can lead the child to conceptualize the fundamental and pervasive schemes of modern science. Accordingly, the primary objective of the COPES Assessment materials is to ascertain whether the child has mastered the concepts underlying his experiences with the Activities. It is important that his goal of the Assessments be kept in mind, in contrast to such alternatives as finding out how the child remembers specific details of what was done, or the degree to which he has acquired a useful skill. The emphasis on mastery of concepts is intentional: it is not that the alternatives are unimportant, but rather that the conceptual goals are more germane to COPES.



Throughout the Activities, emphasis is placed on concepts and relationships rather than on the specific phenomena, or "facts," and so it is in the Assessments. However, what seems a simple relational idea for an older child may be a quite difficult task for the younger child. To assimilate a new explanatory idea into the body of previous ideas, the child may need a great deal of help in what the psychologist, Jean Piaget, calls accommodation--the transformation of previous experience to facilitate the assimilation of new experience. There will also be individual differences in the ease with which children assimilate new ideas, and these differences may appear in different contexts. The same child may readily reach mastery of one concept, but have to struggle with another.

For these reasons, two kinds of Assessment materials have been prepared for use within each grade: Screening Assessments, designed for group administration to ascertain which children have attained mastery of the concepts; and Individual Assessments, designed for administration to a single child or small group. The Individual Assessments have been constructed to help the teacher focus instruction on those areas in which children need additional help. They are intended for use with children who do poorly on the Screening Assessment.

The form of the Individual Assessment is a series of leading questions that take a specific problem from the Screening Assessment and break the problem down into a series of simple questions. There is an intentional similarity in the small-step approach to concept evaluation and the more successful aspects of programmed instruction. Some children need greater help in building up confidence in their knowledge of the concepts and the small-step, guided inquiry strategy is intended for their benefit. (It is not inappropriate for any beginner, but some might find it tedious.) Using this method, the teacher should be able to identify the difficulty the child has with the concept that the problem is designated to assess.

Involvement of Children

From the beginning COPES has been viewed as a basic elementary science program. It deals almost exclusively with basic science to the exclusion of technological applications. Since COPES involves children in firsthand investigations, no materials, other than worksheets and screening assessments, have been written for children. Reading is not emphasized as a way of finding out. This is not to discredit reading or applied science. There are a number of good elementary science textbooks series being used in schools. There are also many good trade books in science for children. Applied science is dealt with in both sources of reading materials. The teaching materials in COPES have

been designed to take up no more than about 80 percent of the time usually allotted to science in the elementary school. It is therefore suggested that COPES be used as the core of the elementary science program and be supplemented with standard reading materials.

The COPES curriculum is action centered. Almost all activities require that explorations of a nonreading nature be carried out by individuals or by small groups of students. For this reason, there is opportunity for continuous development in grades K-6 of such skills as estimating, experimenting, interpreting, measuring, observing, ordering, predicting, and recording. We believe that such active exploration on the part of children is imperative if they are to learn, rather than memorize, concepts selected to build faith in the conceptual schemes of science.

Involvement of Teachers

The teacher is the key to the success of any science program. COPES is no exception. If anything, the teacher assumes a more critical role in COPES than in most other science programs. Since there are no textbooks for children, all learning activities must be initiated and judiciously directed by the teacher. The individual Teacher's Guides provide guidelines by which each activity may be introduced and developed. Allowances are made in them for considerable choice as to the manner and materials each teacher may choose to implement an activity.

Other than a kit in mechanical energy, used in the 1967 Pilot Study, there are no prepared kits of equipment and materials. All activities have been designed to use materials that are readily available. The teacher or a helper, however, must assemble the materials following the directions provided under Preparation for Teaching in the Guides. The teacher must also reproduce copies of worksheets and assessment materials for the children. Since COPES is a highly teacher-dependent elementary science program, it is recommended that a teacher have some inservice training before he or she undertakes to teach COPES. Such preparation for teaching COPES has been found to be especially helpful in the upper grades. Those teachers who have taught COPES in the elementary classroom have thus far found it to be a highly rewarding and stimulating experience.

In succeeding chapters of this report an effort will be made to discuss problems encountered and procedures adopted in developing the COPES curriculum as it has been briefly described above.

CHAPTER III

THE COPES LEARNING ACTIVITIES AND ASSESSMENTS

Review of Procedures Used in the Pilot Study

The primary purpose of the Pilot Study was to determine the feasibility of a conceptual scheme approach to curriculum development in elementary school science. This was accomplished in a series of steps. In the first step the scientists selected the conceptual scheme, Conservation of Energy, and suggested ways in which it might be demonstrated. These tasks were followed by the development of learning activities, judged to be appropriate in leading children to an understanding of selected concepts which supported the conceptual scheme. The learning activities were initially proposed by scientists, science educators, and learning psychologists working as individuals and/or in teams. Once the activities were formulated and then checked to find out if they "worked" as anticipated, they were tried out with children. Based upon the outcomes of tryouts with children the activities were either rejected, accepted, or revised in order to make them suitable. The activities were then grouped into sets and the sets grouped into series of sequences expected to lead in a progressive manner to the understanding of the Conservation of Energy. The schematic on page 9 shows how the sequences were arranged to move upward through two channels, thermal energy and mechanical energy.

Concurrently with the development of learning activities for the Pilot Study, tests were developed to assess children's understanding of the concepts with which the activities dealt. Once the activities and tests were in hand teachers then guided selected K-6 classes of elementary school children upward through the sequences of activities as far as each class' respective abilities permitted. In this way the levels of difficulties of the activities were established. The tests were given at appropriate intervals to determine whether children were, in fact, learning the concepts and whether there was developing a progressive sophistication in their understanding of concepts from grade level to grade level.

The procedural steps described above were expected, at the time, to be appropriate for the Pilot Study. As reported in our final report of the Pilot Study, our expectations were sustained. We therefore expected to enter the Development Phase of COPES using the same general procedure with modifications to accommodate, within the curriculum, the concurrent

development of several conceptual schemes with interaction among them wherever desirable.

Preliminary Work on a Second Conceptual Scheme

On July 14, 1967, at a time when we were enthusiastically tooling up for the three-year effort to complete the Development Phase of COPES, we received a telephone call from the Office of Education informing us that the Development Phase was not to be funded. The explanation for this devastating announcement was that, under its new leadership, there had been a change of policy in the Bureau of Research and no new curriculum projects were to be funded. This action was vigorously appealed and, after face-to-face negotiations with the director of the Bureau, a supplementary grant was given to the Project in order to maintain a minimum staff of key people for one year. During the year (September 1, 1967 to August 31, 1968) we were to renew our efforts to obtain funding for the Development Phase from other sources and to move ahead on the project in whatever manner promised to be most productive.

The staff considered several alternatives, as next steps. One was to develop K-2 materials for the entire COPES curriculum. This was rejected since it was considered risky to develop such materials without knowing what the upper grade curriculum materials would call for by way of lower grade preparation. A second alternative was to select the remaining conceptual schemes to be dealt with in the curriculum and develop general ideas about ways in which teaching materials might be prepared for them. The second alternative was rejected since we could not anticipate such an effort producing anything of a concrete nature, such as the teaching materials produced for the Pilot Study, that might be readily used by future curriculum developers to encourage the introduction of something of the COPES approach into their curriculum materials. A third alternative was to select a second conceptual scheme and develop teaching materials for it in a manner comparable to what had been done with the first conceptual scheme during the pilot study. It was eventually decided that the interim year could be spent most productively by proceeding in accordance with the third alternative.

When the Conservation of Energy Scheme for the Pilot Study was chosen, the scientists were convinced that they were selecting a conceptual scheme that was broadly pervasive in the sciences, as well as one of the more difficult schemes to develop conceptually with elementary school children, and hence a good one to use in a feasibility study. When the scientists were faced with the task of selecting another conceptual scheme they applied similarly rigorous criteria. The outcome was the selection of The Statistical View of Nature as a second conceptual scheme to be developed in the COPES curriculum.

At a highly interactive all-day work session, scientists representing the fields of biology, chemistry, geology, physics, and mathematics, explored the great variety of ways in which the statistical view was applied in their respective disciplines. From their suggestions such subsidiary concepts as the following were identified as being basic to this scheme: properties, variability, average, frequency distribution, sample, chance, random events, the unpredictability of random behavior, and probability. The scientists also cited a number of examples from their respective fields that might be used in writing learning activities to demonstrate one or more of the above concepts.

The responsibility for developing the learning activities, trying them out, and arranging them into appropriate sequences from Kindergarten through Grade 6, was shared by all senior members of the staff which consisted of the equivalent of about four full-time people. (A list of personnel participating in the development and testing of the SVN Activities during the interim year of COPES is included in Appendix A.) The staff met frequently to discuss and evaluate proposals, to evaluate materials as they were written and distributed to them for review and, to decide who would assume responsibility for what future writing assignments. Due to limited funds, the COPES laboratory school for elementary school children that had been organized for the Pilot Study was not reactivated during the interim year. However, at mid year an elementary science teaching specialist was added to the staff to field test samples of the new teaching materials in a nearby public school. Because of limited time for tryouts in the schools, not all activities were school tested. However, all activities were tested in-house to make certain they worked.

A total of 67 learning activities dealing with The Statistical View of Nature were written and organized into a teacher's guide of 249 pages.³ The guide was divided into three sections. Section A included 59 activities considered to be appropriate for Kindergarten, first, and second grades. Section B included 58 activities considered to be appropriate for grades 3 and 4. Section C included 124 activities considered to be appropriate for grades 5 and 6. (See Appendix B for the introductions to each section of the guides, the titles of activities, and samples of teaching materials.)

When the entire Development Phase of COPES was completed, its products consisted of a teacher's guide for each of the various elementary school grade levels, including K-1. As the six guides were written in sequential order, from K-1 through Grade 6, changes were made in the form and writing style whenever experiences indicated such changes would be desirable.

³A Preliminary Teacher's Guide for a Tentative Sequence of Activities Developing the Statistical View of Nature. COPES, New York University, New York, August, 1968 (Unpublished).

As will be noted from an examination of sample activities included in Appendix B, each activity, in this interim phase of guide production had a classification number, a title, a short overview, a list of materials, instructions on how to prepare for teaching, and suggestions for teaching. In the section on suggestions for teaching, what the teacher is to do, why she is to do it, and what she is to expect are often included in sentence after sentence, within the same paragraph. It will also be noted that each page is a relatively busy one with little white space to break up the page. The activities in each section are not grouped into sets that deal with related outcomes. However, there is a sequential progression of activities within each section. In other words each activity builds upon the preceding activities and prepares children, both in terms of skill and concept development, for succeeding ones.

Whereas the format in which these activities were prepared was quite similar to the one used in The Teacher's Guide for the Conservation of Energy Sequence, it had been written for the more scientifically sophisticated elementary school teacher. This was done because initially it was thought that COPES teaching materials could be used only by such teachers. However, it has been found that, after some inservice work, the average teacher can handle the COPES teaching materials very well. For this reason the materials for the SVN Guide were written for the less sophisticated teachers.

During the year in which these activities were being developed no tests or other assessment materials were produced. In fact, it was a real struggle, with the limited staff, to complete the task to the stage of development represented by the materials contained in the guide. Many hours of staff conferences were given over to discussion of which concepts were to be developed and to arrive at some reasonable consensus regarding the operational definitions of the concepts. Most of the writers were science educators and the manner in which they dealt with certain basis concepts were frequently challenged by the working scientists on the staff. Such confrontations were more frequent and more heated than had been experienced during the Pilot Phase or was experienced subsequently in the full Development Phase. In fact, the differences of opinion regarding some activities were not resolved prior to their reproduction in the teacher's guide. For that reason the director of the project insisted that the title of the guide be qualified with the use of the terms "preliminary" and "tentative."

Only 50 copies of the teachers guide for the Statistical View were reproduced. Ten were sent to the COPES monitor in the Office of Education. Twenty-five were used by students in a methods course on the teaching of elementary school

science. This was done as a minimum field test of the guides suitability for use with teachers. The instructor of the methods course had not only written a number of the activities but had also assumed major responsibility for editing the volume. She got reactions from her students to most of the activities. These were tabulated and summarized. In general the students found the activities to be clear and informative. For many of them the concepts being developed were new. In other words these college students were actually learning, for the first time about the Statistical View of Nature, as they performed the activities.

At a later time another member of the staff used copies of the guide to introduce one of his graduate classes in science education to The Statistical View of Nature as a conceptual scheme in science. Most of these students had the equivalent of a masters degree in one of the sciences, however, many of them found it difficult to accept the statistical view as a big idea that should be developed in science, particularly in the elementary school. They felt it should be done in mathematics. This, no doubt, indicates a deficiency in their scientific training. It may also explain, in part, why in the early stages the science educators and the scientists on the COPES staff experienced communication problems in dealing with the various concepts within this scheme.

There was another factor that became a difficult problem in developing materials for this scheme, and it was this: All had agreed that real things and actual phenomena should be used wherever possible to develop the concept. Analogies such as games should be avoided. The intent was indeed a noble one but we found it impossible to develop certain concepts such as chance, randomness, and probability without resorting to the use of games. The stubbornness that develops from such good intentions frequently produced time-consuming roadblocks to accomplishing many tasks in curriculum development, especially where the course it should take is uncharted. For many of us on the project, who had become accustomed to the reorganization of familiar material as curriculum development, such delaying experiences became highly frustrating.

As one looks back, now, over our experiences with the Statistical View of Nature during the interim year, it would appear that the project benefited greatly by having one more go at a single conceptual scheme, uncluttered by concurrent consideration for the other schemes. This seems especially significant with reference to relatively new science ideas being developed in elementary science. It is doubtful that the statistical view would have been explored as completely had it been left for consideration concurrently with the other schemes. Not all of the statistical view activities found their way into the COPES guides as they were published for release to schools. Furthermore, some of the Statistical View activities in the published guides were developed subsequent to production of the preliminary guide for the Statistical

View guides. Even so, the one year we spent with this tough one was time well spent in terms of the big job that was still ahead of us.

Preparation of the Teachers' Guides for the Total COPES Curriculum

The Final Start on the Development Phase

On March 5, 1968 the Associate Commissioner for Research of the U.S. Office of Education was apprised of our unsuccessful efforts to obtain funding from NSF, or other sources, for the completion of the Development Phase of COPES. He was also brought up to date on other work being done during the interim period. He was then asked to consider reactivating the proposal which had been submitted the previous year. On March 15, a letter was received from the Director, Division of Elementary and Secondary Education, Office of Education, encouraging us to update our original proposal and submit it for reconsideration. This was done on April 1, 1968, however, it was not until late in the fall that we received unofficial word that we were to be funded. In fact the grant was not officially awarded until January 31, 1969. Because of this delay, we did not officially get under way until the second semester of 1969.

One of the first official functions to be performed after receiving word that the Project was to be funded for the three-year Development Phase, was to hold a special meeting of the science consultants for purpose of determining the additional conceptual schemes which were to form the framework of the full COPES Curriculum. As previously reported two of the Conceptual Schemes had already been selected and teaching materials dealing with them had been prepared. Based upon this experience it was decided that only three more would be selected, thus making a total of five. In hierarchical order the five conceptual schemes are: 1) The Structural Units of the Universe; 2) Interaction and Change; 3) The Conservation of Energy; 4) The Degradation of Energy; and 5) The Statistical View of Nature. The substance of these conceptual schemes has been discussed earlier in this report on pages 4-7.

The COPES Laboratory School was reactivated and a full-time elementary science specialist was employed to manage it. On the fifth floor of the Physics Building, 4 Washington Place, a lounge with adjoining kitchen were converted into a classroom. Special lighting fixtures and chalkboards were installed. Desks were supplied that could be used as work tables. Bulletin boards and supply cabinets were arranged around the room. The laboratory school classroom was located on the same floor and adjacent to

the COPES offices and workrooms; a most convenient arrangement. During the spring semester, 1969, the laboratory school, with an average attendance of about 12 children, was in session for 1-1/2 hours four afternoons each week. Most of the class time during this semester was given over to trying out selected teaching materials from the Statistical View Guide. Audio tapes were made of each class session and later used by the elementary science teaching specialist in her reports to other members of the staff. These reports were then used by the staff in evaluating the corresponding teaching materials.

A COPES Laboratory School Report for May 14, 1969 is included in Appendix C. It should be noted that this report covers the class session in which the two sample activities included in Appendix B were used with children in the laboratory school. (C-21 Chance and Probability and C-22 Probability and Numbers of Possible Outcomes.) For the next two academic years (1969-1970 and 1970-1971) the laboratory school operated in this manner. During July and August of 1969 and 1970, the laboratory school was in session for two hours every morning for a period of eight weeks. The average daily attendance during the summer was approximately 18 children.

By making prior arrangements with the person in charge of the laboratory school any staff members could observe children during times that they were working with the materials that he had prepared. In this way the laboratory school, during the academic years and the summer sessions in which it was operated, served as a readily available source of feedback to the writers of teaching materials.

During the spring semester additional staff were recruited for the summer session (July and August 1969). The expanded staff was to work on all fronts with the three unexplored conceptual schemes. In addition to the director (a physicist), the associate director (a science educator), and the assistant director (a physical chemist), the following were on active duty during the summer: two evaluation specialists, one biologist, one geologist, four science teaching specialists, two laboratory school teachers (one for each half of the summer), two teaching assistants, two technicians, two secretaries, and one clerical assistant. One science teaching specialist worked with each of the four scientists in teasing out ideas primarily from one of the new conceptual schemes, Structural Units of the Universe, and designing corresponding activities that were then tried out by technicians to see if they worked. Some of these were later tried out with children in the laboratory school. By the end of the summer a considerable quantity of material had been produced. However, much of it still needed to be worked over and tried out again before decisions regarding its suitability could be made.

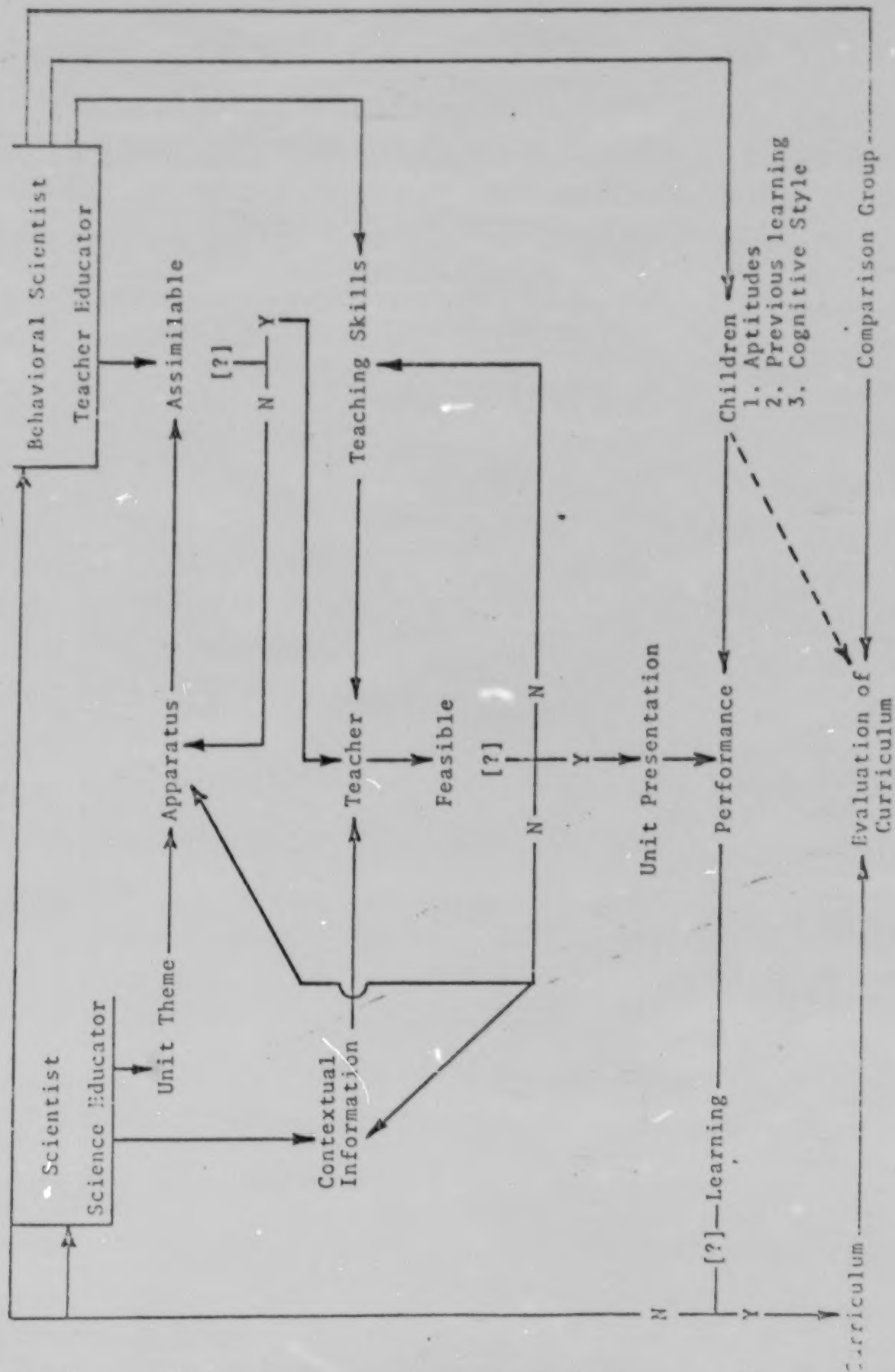
During the summer of 1970 some new staff people were added and the work was focused primarily upon another conceptual scheme, Degradation of Energy. Because of the pervasive nature of the conceptual scheme dealing with Interaction and Change, work upon it went on concurrently with work upon learning activities for the other four schemes.

From the time of the Pilot Study we had been concerned about the manner in which the COPES Curriculum materials, or teaching activities, should be evaluated. As we entered the Development Phase this became a problem of paramount importance both in terms of the selection of activities for grade-level guides and in terms of the procedures that would clearly articulate the Development Phase of COPES with its Field-Testing Phase.

The evaluation procedures used in the Pilot Study were critically reviewed and a decision was made not to use them further. A new overall plan was developed by our evaluation specialists to serve as a future guide for COPES. The plan proceeded along two lines. With regard to children's mastery of the concepts presented in COPES Activities, new evaluative modes were to be developed which stressed the child's development of his own expectation from an activity and his explanations of what he observes, in addition to the necessary but insufficient goal of "getting the right answer." The emphasis was to be on "mastery" of one concept as a necessary preliminary to the learning of collateral or more general concepts. This criterion-oriented assessment differs in principle from the usual assessment that typically results in differentiating one child's accomplishments from those of his peers.

The second emphasis was to be internal to the development of new activities, as it had been for the activities developed for the pilot study. The model, as shown on page 20, depicts a system of interactions of staff members with different competencies and goals, all bearing on the psychologically complex product that is a COPES activity. The upper portion of the chart shows that an idea is evolved from a social context and evaluated for how the child is likely to react to it ("assimilate it" in Piaget's words). Then it is presented to an experienced teacher who has the requisite skills and knowledge of science for a judgment of its feasibility in a classroom setting, or who will actually try it with children to see if it is feasible. (Y of course, means yes and N, no.) After all of the staff agree on its scientific validity, psychological assimilability, and teaching feasibility, the activity becomes incorporated into a teaching guide and will later be presented as sequences of activities to many children in a variety of classroom settings. The children's performance, shown along the bottom portion of the model, is evaluated in light of their aptitudes and other inputs to the learning experience.

Outline of Proposed System for COPES Evaluation



If, in terms of the final assessment, learning has occurred--the children have mastered the concepts--the set of activities is retained as a part of the curriculum.

The upper two-thirds of the chart represents fairly accurately what was done in developing the present editions of the teachers' guides. The next to the bottom line represents what we had proposed to accomplish in the Field Testing Phase of COPES. We hope that some way may still be found to accomplish this. The bottom line represents an ultimate test, in which the COPES Curriculum is compared with other methods of teaching. This may never be accomplished.

In producing the present teacher's guides the staff was involved in many ways other than preparing teaching activities, trying them out, evaluating them, and revising them. One of their more challenging tasks had to do with selecting the activities that were judged to be suitable for each grade level, arranging them into coherent subsequences which could in turn be fitted together into a grade sequence that would hold together conceptually as it progressed from the first to the last activity. Each senior member of the staff contributed generously in conference after conference dealing with the many problems inherent in the major task of sequencing. However, the final decision regarding such matters ultimately were made by the assistant director of the Project in consultation with the director and the associate director.

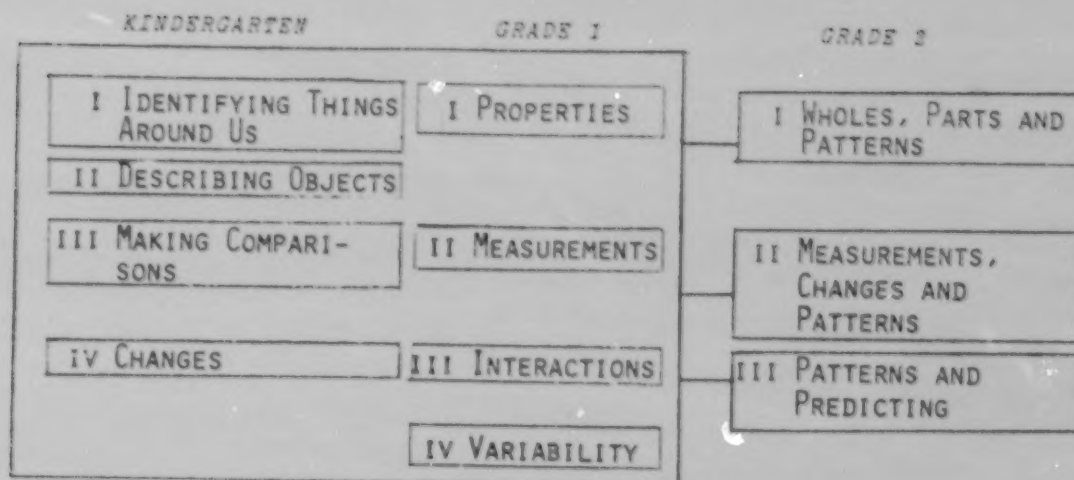
Because of the experience the directors of the Project had previously had in developing a K-6 sequence of activities for each of two conceptual schemes, it was not difficult for them to move up or down grade levels in helping staff develop activities at whatever level they might be working. At any one time in the COPES shop it was quite possible to find staff members working on activities at all grade levels. No effort was made during the formation period to restrict members of the staff to the preparation of activities for only one grade level. In part this was accounted for by the fact that it was not until we had a large number of activities produced did it seem appropriate to begin looking at them in terms of grade levels and sequences.

The remainder of this section will be given over to a discussion of how and why the Teacher's Guides turned out to be as they are presently.

K-1 and Grade 2 Guides

As will be noted in the hierarchical schematic for the conservation of Energy on page 9, we have been committed, from the time of the Pilot Study, that the COPES Kindergarten, Grade 1 and Grade 2 teaching materials should provide children with the conceptual framework needed for entering the main sequences of the COPES Curriculum beginning at Grade 3.

The arrangement and titles of the topics, dealt with in each of the first three grade levels, reflect the hierarchy of the science concepts that are developed in K-2:



If the titles of the above topics are compared with those from K-2 in the schematic for the Pilot Study (page 9) several differences would be noted. These are accounted for by the fact that the K-2 materials for the pilot study were limited basically to preparation for the activities leading to concepts related to the Conservation of Energy. The present K-2 materials have been developed to provide the conceptual framework needed to enter sequences dealing with all five conceptual schemes. Thus such topics as Changes, Interactions, Variability, and Wholes, Parts, and Patterns are introduced.

It took much more time and much greater effort to develop the K-2 materials than originally anticipated. The present edition is the outcome of numerous reorganizations and redrafts of material. To some extent this was accounted for by the necessity to hold off completion of final drafts until the upper level sequences for all five conceptual schemes had been more definitely established. In part, it was also accounted for by the change in format and writing style. Finally, after a first draft of one complete K-2 edition had been prepared the decision was made to change substantially the orientation and content of the sequence. This decision made it necessary to rewrite most of the activities which further delayed their publication by at least six months. To some of the staff this delay appeared to be unnecessary at this stage in the development of COPES materials. However, it is now generally agreed that the change was well worth the effort in producing a more finished product of higher quality.

One of the fundamental operating principles applied in developing COPES materials has been that basic learning skills, or processes,

must be developed concurrently with the concepts. Different members of the staff had ideas about what skills were important and which ones should be developed in COPES. However, it became evident, as certain members of the staff were faced with the task of putting together the K-2 materials, that there was not complete agreement upon which skills were needed and which should be emphasized. After numerous conferences agreement was finally reached that the following nine skills should be developed in COPES: analyzing, classifying, communicating, experimenting, interpreting, mathematical reasoning, measuring, observing and predicting. It seems appropriate to note here that Project decisions such as the above, were generally made by the staff with the appropriate interests and competencies represented. Such an approach to decision making took time but in the long run was considered to be an essential feature of our work.

It was with the production of the most recently revised K-1 Guide that the format and writing style were changed quite considerably from those used in the Conservation of Energy or the Statistical View of Nature Guides. One major change resulted from the decision that the objectives for each activity should be highlighted for the teacher more than had been done previously. In keeping with the "skill-concept" principle referred to earlier, it was also decided to state the objective in a form that more clearly indicated how these were related. After several major attempts at this most demanding task it was decided that the objectives should be stated in a style that would make clear which skills are being applied in the activity, the phenomena to which the skills are being applied, and finally, the concept goals which result from the application. For example, in the first activity in the Kindergarten part of the K-1 guide, the title of the activity is, Some Things Around Us. The teaching objectives for this activity are stated as:

<u>Skills</u>	<u>Phenomena</u>	<u>Concept Goals</u>
Observing	things around us	to emphasize the importance of observational awareness
Communicating	by making records or pictures	to build a collection of objects with different properties

Reactions from elementary school teachers to the above style of stating the teaching objectives of COPES activities were un-animously favorable. Therefore the style was adopted for the K-1 and Grade 2 Teacher's Guides.

It was also decided that, for the K-1 and Grade 2 Activities, it would be desirable to list selected new terms to which children would be introduced in each activity as Key Vocabulary. This was done not with the intention that teachers should encourage children to learn definitions of the new words, but with the intention that teachers would encourage them to use the new words where appropriate. Each time the new word is used in the guide it is underlined to alert the teacher. Here are examples of Key Vocabulary as listed in some of the Kindergarten activities: change, living, environment, to group, a group, shape, and record. None of these terms is technical however they are frequently used with specific meanings in the activities. Furthermore, by using them properly children improve their facility to communicate about scientific investigations and ideas.

One of the major changes in format came about in an attempt to meet a frequent teaching criticism of The Teacher's Guide to a Conservation of Energy Sequence. Teachers claimed that they had found the section dealing with "Suggestions for Teaching" difficult to follow. Since the section often included, within one paragraph the instructions for teaching, explanation of why such a procedure is desirable, and background material for the teachers, teachers complained that, after they had read the paragraph, they were generally confused regarding what they were to do. Frequent rereading was required to get at what she was required to do as contrasted with informational material for her. Once mastered by the teacher she found the guides extremely useful. However, such mastery could not be obtained on a first or even a second reading.

As a consequence of the above criticism it was decided to present the suggestions for teaching in a two-column page. The column on the left was to be headed INSTRUCTIONAL SEQUENCE and the column on the right was to be headed COMMENTARY ON THE SEQUENCE. Thus in the left column would be listed only those things the teacher was to do with the class. The instructions were to be written very specifically and arranged in a developmental sequence. Parallel to each instruction in the left column was to be listed, in the right column, any comments that were considered to be appropriate. Teacher's reactions to the double-column format have all been highly favorable and it has been used for all COPES Guides.

As will be noted in the activities selected from the Kindergarten part of the K-1 guide and included in Appendix D, each activity consists of the following sections:

- Title of the topic to which activity relates
- Title of the activity
- Teaching Objectives
- Key Vocabulary
- Materials
- Preparation for Teaching
- Instructional Sequence and Commentary on the Sequence

The 19 kindergarten activities are organized into a series of sequences under five topics as follows:

TOPIC I: Identifying Things Around Us

Activity 1: Some Things Around Us
Activity 1A: Creating an Environment for Living Things
(optional)
Activity 2: Arranging Objects into Groups
Activity 3: How to Show that Objects Belong to Groups
Assessments

TOPIC II: Describing Objects

Activity 1: How Is It Different? (Objects Have Different
Properties)
Activity 2: Grouping Materials as Solids or Liquids
Activity 3: Grouping by Properties
Activity 4: What Are Its Parts?
Activity 5: Small Parts
Assessments

TOPIC III: Making Comparisons

Activity 1: Comparing Dimensions
Activity 2: Comparing Weights
Activity 3: Comparing Number of Objects in Groups
Assessments

TOPIC IV: Changes

Activity 1: Changes in Living Things
Activity 2: Sensing Motion
Activity 3: Pushing and Pulling
Activity 4: Magnetic Pulls
Activity 5: Melting

In addition to the general introductory material dealing with discussions of the COPES rationale, the five conceptual schemes, the important role of the teachers, and the "Skills-Phenomena-Concept Goals" analysis of objectives, the introductory part of the Kindergarten section of the K-1 Guides presents the following as an overview of the kindergarten topics:

OVERVIEW OF COPES KINDERGARTEN TOPICS

This section presents an overview of each of the four topics in the Kindergarten Sequence, and a description of the assessment objectives and materials designed for the sequence. More detailed descriptions of the topics will appear with the activities, and more specific instructions for assessment will appear with the assessment materials.

TOPIC I: IDENTIFYING THINGS AROUND US

Understanding the nature of matter - what parts and wholes need to be thought about, how they interact, what changes occur - is much of what science is about. Basic to the answers to these questions is the idea that those things around us, (or objects, as the children quickly learn to call them) have characteristics that children use to describe them, called *properties*. The advantages of carefully observing and recording properties evolve in the Topic I sequence; the child's environment, augmented by a terrarium or aquarium where possible, provides the laboratory within which he learns first to recognize and label certain properties of familiar as well as new objects; second, to use properties to classify objects into groups; and third, learns a simple way to make a record of his groupings according to different properties.

TOPIC II: DESCRIBING OBJECTS

Additional properties, including functions as well as physical attributes, are introduced in the first activity of this topic. The learner next discovers that some very useful categories, like "liquid," or "living," are really names for properties in combination, rather than separately. Then he is introduced to the interesting fact that objects that have been grouped with regard to one property may also be regrouped with other objects that have been grouped with regard to other properties, or combinations of properties.

The last two activities in this topic provide experiences in part-whole relations, and the observation of parts of objects both living and nonliving. These activities lead to later emphasis on the structural units in nature, and to the pervasive idea of a system.

TOPIC III: MAKING COMPARISONS

In Topics I and II, properties were used to group objects and to describe them, but the properties, in general, were different: red and yellow are different colors; liquid and solid are different states of matter. In Topic III, gradations, or differences in intensity, or in the degree to which an object has a given property, are the focus of the three activities. First, the child learns the ideas associated with linear dimensions, separately, as length, width and height, and in combination, as in the concept of size. (Volume and mass are not introduced as vocabulary at this

grade level.) Second, the learner experiences differences in heaviness (weight as a conceptual term is introduced later). Finally, by counting and comparing, the child begins to consider the number of elements in a group as a property of the group, since he may subsequently be differentiating whole objects by the number of identifiable parts in them.

TOPIC IV: CHANGES

Throughout the year, changes in the child's environment have been occurring. Plants and animals, including the child, have grown; buildings have weathered, or been removed, or new ones built. A more directed set of observations and discussions about change characterizes this set of activities. Motion is defined as a change in position, and discussion ensues regarding the concept that a change in motion occurs only when a force is applied. Ice is melted, and the conditions of its change from solid to liquid are explored. Food and other objects change when placed in water, and in more than visual appearance when heat is added. The learner's attention is focused on changes, the causes of change, and the idea that interactions between objects (and/or heat) result in changes. This topic leads directly to one of the major concepts in COPES - Interaction and Change.

In the introduction for each topic the scientific rationale for the material is discussed. An overview of the topic is presented along with the concepts that are to be developed. The following is the introduction to Topic I as it appears in the Teacher's Guide. It is presented here as an example.

TOPIC I: IDENTIFYING THINGS AROUND US

INTRODUCTION

Understanding the world around us -- its structure as well as its behavior -- is what science is all about. Basic to providing satisfactory answers to the "what, how, and why" of nature is careful observation of the properties of behavior of objects in our real world. Properties describe objects, how they appear, and how they behave. Properties include such things as shape (round, square, etc.), color, and texture or hardness. The objects in a pencil box may all possess the same properties, e.g., shape, having an eraser or being used as a writing tool. These are common properties for pencils, but each may not have the property of length, for example, to the same degree; i.e., they may have different lengths. Observations of properties (of objects or groups of objects) pervade the entire COPES curriculum (1-6). Thus, in Topic I, taking advantage of the innate curiosity of young children, activities are provided which help them to observe more carefully -- and to learn that objects familiar to them can be described by properties which they can readily see.

Learning to group familiar objects into categories of common properties (selected by the child himself) helps not only to reinforce the concept of property but also to develop the skill of classification -- a skill basic to science as we search for patterns from which generalizations and theories can be derived.

The initial activities make use of the children's immediate and familiar environment -- their classroom and schoolyard. They develop their own criteria for categories based upon the properties of familiar objects. It is likely that they will introduce *living or nonliving* as a criterion for grouping. Although scientists find the concepts of living and nonliving difficult to define exactly, these terms are not so obscure at the experience level of children. This is one way to group objects. However, the science (activities) to be developed later, in many cases, refers to objects generally, whether living or nonliving. For example, the property of possessing the color yellow may include within that group a crayon and a yellow rose. Wherever feasible, both living and nonliving objects are used in the COPES program. One purpose of this is to help children realize that the science concepts we develop apply to living things as well as to "physical" objects. Of course, some of the special properties unique to living things, such as their need for food in order to grow, or that they react to situations in much different time periods, will emerge as the curriculum develops.

In the last topic (IV) of the Kindergarten Sequence, activities are directed to observing that living things do change in size, color, shape, etc., and that it often takes considerable time for this to occur. Therefore, an optional activity (1A) is recommended as part of the present topic. This activity suggests that, in addition to using the local outside environment, a special one, such as an aquarium or terrarium, be established in the classroom early in the year. Thus, opportunities to observe the properties of living and nonliving things can be provided within the classroom as well.

In general, the purposes of the activities in Topic I are to give children experiences in observing objects closely (*Activity 1*), to learn to classify them into groups based upon a property criterion (*Activity 2*) and to learn how to recognize and record a group of objects possessing a common property (*Activity 3*).

In all these activities, arranging objects (or "things") is used. Later, a more scientific term "objects" will be introduced as part of the vocabulary and gradually substituted for "things."

The science concepts to be introduced within this topic can be stated as follows:

1. Objects (living or nonliving) can be described in terms of measurable properties.
2. Objects are sometimes described in terms of functional properties: (e.g., balls are classed as toys; pencils, as writing tools, etc.)

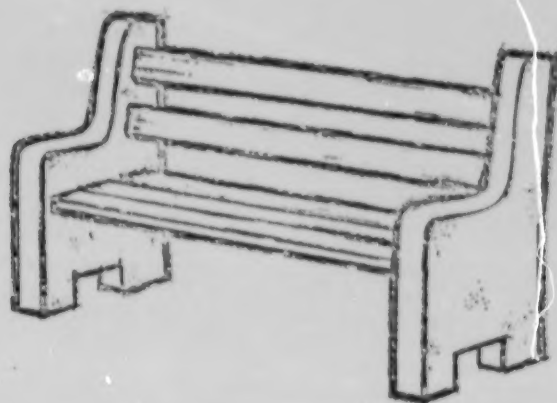
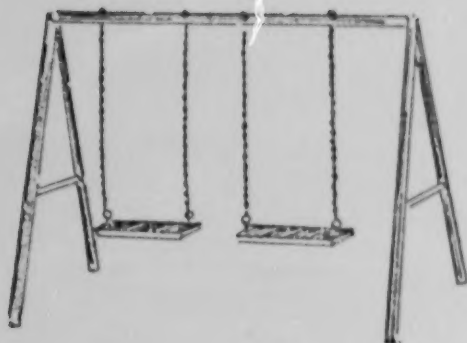
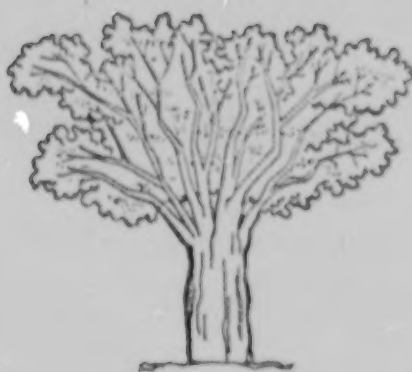
The director and/or the assistant director generally assumed responsibility for writing all introductions and overviews after the activities had been selected and organized under appropriate topics.

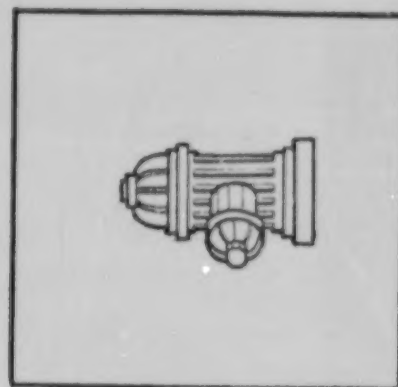
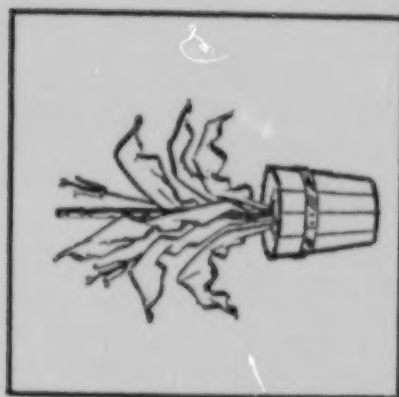
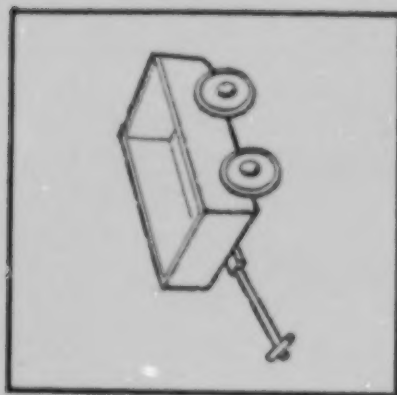
Following the teaching activities for each topic in the Kindergarten Teacher's Guide are materials prepared to assess whether mastery of the concepts dealt with in the activities for that topic has been attained. Mastery is assessed by a screening instrument that can be administered to the group; the teacher reads instructions aloud and the children respond by making X's, underlining, or other simple ways to show they understand a concept represented in pictorial format. For those children whose performance on the group screening assessment is less than the teacher expects, individual assessment activities, often approaching re-learning of the concept, are provided for most topics. For others, the teacher is urged to re-teach the topic as needed.

One page of assessments having to do with "learning about groups and grouping" is reproduced on page 30. For these and other sets of pictures in this part of the assessment, children are instructed orally to "Draw a line between the two pictures which go (belong) together." In the first set of pictures on page 30, the tree and the potted plant go together; in the second it is the swing and the bench. A second page from another part of the assessment for this topic is reproduced on page 31. Here the instructions are to "Put X's on the three pictures that go together." X's are expected to be put on pictures of the rabbit, the potted plant, and the dog. There are, in all, seven pages of such assessment materials following Activity 1: Identifying Things Around Us. In these assessments, not only the concepts of group and grouping are assessed, but also the skills of observing and recording. Wherever a child has difficulty with these assessments the teacher has three alternatives. She can re-teach the material in the Topic I activities; she can use the assessment materials themselves to teach the concepts and skills; or she can use her own collection of cutouts for children to use in learning about groups and grouping.

In the Kindergarten section of the K-1 Guide there are 84 pages of activities and 65 pages of assessment materials. The relatively large number of pages given over to assessment materials is accounted for, in part, by the fact that all items are presented in pictorial format. Teachers are expected to reproduce copies of the assessment sheets for use with their children. A separate packet of those sheets which are to be reproduced for children's use are available for the K-1 Teacher's Guide in the form of an Assessment Kit.

The Grade 1 part of the K-1 Teacher's Guide was prepared in the same format as the Kindergarten section. There are 24 first grade activities organized in a series of sequences under four topics as shown on page 32.





TOPIC I: Properties

- Activity 1: Reviewing Properties
- Activity 2: Solids, Liquids and Gases
- Activity 3: Sizes, Colors, and Shapes
- Activity 4: Different Ways of Grouping Objects
- Activity 5: Taste as a Property
- Activity 6: Odor as a Property
- Activity 7: Germination, a Property of Most Seeds
- Assessments

TOPIC II: Measurements

- Activity 1: Ordering Objects in Terms of Size
- Activity 2: Measuring and Estimating Amounts
- Activity 3: Combining Volumes
- Activity 4: Equivalent Volumes of Liquids and Pourable Solids
in Different Shaped Containers
- Activity 5: Extending the Concept of Conservation of
Material
- Activity 6: Measuring Lengths
- Activity 7: Warm and Cold/Using a Thermometer
- Assessments

TOPIC III: Interactions

- Activity 1: Changes in Environments
- Activity 2: Interacting with Water
- Activity 3: Making Solutions
- Activity 4: Interaction Between Magnets
- Activity 5: Experiencing Gravitational Force
- Activity 6: Adding and Removing Heat Energy from Substances
- Assessments

TOPIC IV: Variability

- Activity 1: Variations in Motor Skills
- Activity 2: Variations in Physical Characteristics
- Activity 3: Variations in Events
- Activity 4: Variation in Germination Time
- Assessments

The following is an overview of Grade 1 topics as it appears in the Teacher's Guide:

OVERVIEW OF GRADE 1 TOPICS

When COPES Kindergarten teaching materials are compared with the Grade 1 materials, the spiral development of concepts and skills that is typical of the COPES curriculum becomes increasingly apparent. The concepts and skills introduced in Kindergarten are further developed in Grade 1 at a level commensurate with the abilities of first-grade children. New concepts and skills dealing with properties, measurements, and interactions, that are introduced in Grade 1 are considered to be prerequisite to those that will be developed at subsequent grade levels.

TOPIC I: PROPERTIES

To understand nature requires careful observation of the properties of objects with reference to both their functional and physical characteristics. This attention to properties is fundamental to all topics in the COPES curriculum and to all the conceptual schemes with which it deals. For example, before we can infer that an interaction is taking place, or before we can consider an idea as conservation, one or more properties must be identified and measured. The aims of all seven activities in Topic I are to improve the skills of children in observing and recording properties and to widen their experiences with functional and physical properties. The first activity reviews the idea of describing objects by their properties (first introduced in the Kindergarten materials). Other activities that deal with the grouping of objects by using one or more common properties of the objects also reinforce the concept of property. The idea that a combination of properties can be used to define a class of objects, an idea originally introduced in defining solids and liquids, is reinforced in these activities when the concept of a gas is introduced. In still other activities the skill of classifying (grouping) is practiced in situations where many sizes, shapes, colors, textures, and functions can serve as criteria for arranging objects into particular groups. Other activities extend the concept of properties to include the taste and the odor of several different objects.

Whenever appropriate, objects from both living and nonliving systems are used. In the last activity in Topic I, germinative ability is investigated as a unique and functional property of viable (living) seeds. Germination of seed is a biological phenomenon with which subsequent COPES activities will deal in a number of ways.

TOPIC II: MEASUREMENTS

The activities in this topic enlarge and refine both the ideas and skills of Topic III in the Kindergarten Sequence. In the present topic, children will go beyond comparing the gradations or differences in the magnitude of a property. They will be introduced to the quantitative aspects of properties, such as length and volume. The all-important idea of a unit of measure - length or volume - is introduced, along with the idea that the unit may be arbitrary but must be selected so that independent measurements can be compared. Further, "to measure" means to find out "how many" of these units fit the dimension being measured, i.e., the idea of replication.

These activities begin with the ordering of objects; however, the skills involved are more complex than those called for in the Kindergarten materials. Children are then introduced to a unit measure of volume. Water is used as the most convenient medium for this and other purposes in the COPEs curriculum. The additive nature of volumes of water, as well as its conservation within different shaped vessels, is then developed. Once the concept of the conservation of liquid water has been established, this idea is extended to other materials, including clay. Arbitrary units proposed by children are used in developing the concept of replication as a means of measuring a linear dimension whether length, width, or height. The concept of arbitrary units (or scales) is further emphasized as the children are introduced to thermometry using uncalibrated thermometers to which they attach their own scales.

TOPIC III: INTERACTIONS

The activities in this topic have been designed to help children become more aware of some of the many ways in which objects can change and to associate these changes with interactions with their surroundings. This major concept was originally introduced in the Kindergarten materials. The first activity is a rather extensive one having to do with investigations of a number of different environments and the different changes observed in these environments as conditions vary. This is the first activity in the series since the proposed investigations are to be conducted periodically throughout the remainder of the school year at the teacher's discretion. The more specific interactions investigated in the other activities include: the interaction of water with various objects, resulting in absorption of the water; the interaction of magnets with other magnets; the attractive interaction between objects and the Earth, known as gravitational force; and the interaction of heat energy with substances such as candle wax. In all activities, specific interactions are inferred from the changes which the children can easily observe.

TOPIC IV: VARIABILITY

In previous topics, children were involved with the characteristics or properties of many kinds of objects. Classifying objects into groups based upon common properties or sets of properties has helped to establish the concept of the property. The differences in properties between objects in one group and objects in another group further emphasizes the concept. The idea that the magnitude of certain properties of objects, e.g., length, height, etc., can be measured and individual values assigned to individual objects was developed in Topic II. The focus of the activities in this topic is on the values of a particular property as observed in a group of similar objects, called a "population." In some instances, slight differences in values may be observed between members of the population. In other instances, the values of the property in the population may appear to be identical. Close observation (measurement) of this one property, however, reveals gradations or variations. These variations of a particular property found in a population are known as *variability*. In the first three activities, the group or population consists of the children in the class. The properties they observe include their own abilities to do specific tasks, their own characteristics such as hair color or foot length, and

an event important in their lives - the month of their birthdays. In all the activities of personal interest to children, the idea of variability is developed although the word is not taught to be a part of the children's vocabulary. In the final activity, the population observed is that of seeds. Children observe variations in the time for germination. Thus, they are introduced to the concept that, although the (viable) seeds will germinate (just as each child has a foot size and a birth month) a particular seed will possess its own germination time, and a spread or variation of values for the total group is the only way to describe the germination time for that kind of seed - that is, the group exhibits variability in that particular property. This concept is the cornerstone for the development of the fifth conceptual scheme in COPES - The Statistical View of Nature - and will be developed in more sophisticated fashion starting with the activities in Topic IV of Grade 1.

The following is a sample of the introduction to Grade 1 topics as they appear in the Teacher's Guide. As indicated this one is the introduction for Topic II: Measurements.

TOPIC II: MEASUREMENTS

INTRODUCTION

Measurement is fundamental to science both from a conceptual and a process, or "how to," point of view. It pervades not only the entire COPES curriculum, but also any of the new investigatory elementary science programs. In addition to the skill of how to measure a length, temperature, time, etc., fundamental concepts such as a *unit* of measurement, the selection of an arbitrary but not capricious *scale*, the counting of repeating units (*replication*) to fit a dimension, plus the all important concept of *conservation*, are all part of *measurement*.

In the previous topic, various properties by which objects could be described were developed. In the succeeding topic, changes in properties lead to the development of the idea that an *interaction* must take place to cause these changes. But in order to be able to observe the changes, we must first be able to measure a given property. And we must be able to observe a change in the value of that property in order to realize that changes are occurring. Therefore, in this topic, the skills or abilities and the concepts pertinent to measuring the magnitude of a property are developed.

Measurement just for the sake of writing down a number is a useless task--just as stated previously for observing--if used just for the sake of listing descriptions, it can be both useless, and senseless, as well as boring. Skills must be developed, but towards a meaningful purpose. In this topic, not only do we measure to be aware of changes, but also to *compare* -- different sizes of objects, different degrees of warmth, etc.

The concept of conservation is also fundamental to all of science and a central theme of the COPEs curriculum. By conservation, we mean accountability, keeping track of things, whether amounts or numbers.

Thus, the purpose of the measurement activities is to provide children with experience in:

1. comparing objects with respect to the value or magnitude of a property, such as its dimensions.
2. measuring a property to be able to recognize when changes occur.
3. developing the idea of conservation of quantity.

Underlying all three is the necessity of developing the ideas of (1) a *unit of measurement* and (2) a *scale* composed of a series of smaller units. The unit of measurement is developed as fully as is feasible for first graders in this topic. It will be more fully expanded and applied in Grade 2 activities. In the present topic, children are led to understand that *any* unit of measurement is arbitrary but should not be haphazardly or capriciously selected. The size of what is to be measured and the need to compare and communicate measurements guide the selection of a common unit. Children may construct their own units of length; they will have experience with various, arbitrary units of volume; they will also note that units of temperature may be devised to their own scales.

Once the unit of measure is selected, we must then count *how many* of these units fit into the dimension we wish to measure. If it is the volume of a container, we count how many unit measures (of volume) fill or go into the container. If it is length, we count the number of units of length that fit into the dimension to be measured, called replication of units. Note that in using the term length, we are referring to any *linear dimension*, which in common language also includes width and height. To the scientist, all three are simply length measurements. However, to the child, they may have different functions and he may wish to keep them conceptually separate for the time being.

In addition to developing some of the basic skills and concepts of measurement, the activities begin to foster an understanding of the following presequence science concepts:

1. Objects can be described in terms of measureable properties, e.g., dimensions, temperature, etc.
2. The amount of matter in an object can be quantitatively measured in terms of volume (and mass).
 - a. Volume is a measure of the space occupied by the object.
 - a-1 Under ordinary conditions, the volume occupied by an object is conserved (does not change).
 - a-2 Under certain conditions, volumes are additive.
 - a-3 In particular, the volume of water samples is conserved and is additive, although the shape may be altered.

The sequence of activities in this topic starts with a review of comparing the sizes of objects. Children compare dimensions such as lengths, widths, space covered (areas) and space occupied (volumes). In using comparative terms, it is advisable to keep track of the dimension being compared. For instance, the lengths of two straws are used to develop the concept of longer than or shorter than. Since longer than can also refer to time, we must mention that one of the straws is longer in length than the other, since the property of length is being considered. The same applies to concepts of more than, less than, smaller than, etc. The referent, length in the example above, should always be clearly understood. In Kindergarten, comparison is made only between two objects, and thus, concepts of larger than or taller than were introduced. In these Grade 1 activities, the idea is extended to gradations in size in a group containing more than two similar objects. Thus the concepts of largest, smallest, etc., are introduced. Ordering groups of similar objects into graded series showing the gradations in a dimension reinforces these concepts. A new technique of comparing size (volume) is also introduced. When an object is placed in a container of water, the water level will rise. Children discover that the amount of rise is related to the total size of the object (its volume). Objects taking up more space displace more water. In this activity children compare displacements of water caused by different sized objects. The concept of equating the volume of displaced water with the object that was immersed in it may be a difficult concept for first graders, but it is felt that early exposure and applications to additional situations may help to develop notions of such equivalency.

Activity 2 introduces the concept that a container can be used as a "unit-measure" of a substance. In the initial examples, the material is water. Unit-measures are added, and the children should associate the increase in water volume (size of the water sample) with the added unit measures. In *Activity 3* more attention is paid to the concepts that any container can be considered as a unit-measure and that a larger container can be thought of as composed of a number of smaller units. In addition, children combine several unit measures and thus develop more strongly the concept that the combined volume of a mixture of water samples is the sum of the units being combined, necessary to support the concept of conserva-

tion. By now they should be developing a sense of conservation of both volume and numbers.

In *Activity 4*, in addition to reinforcing the concept that any container can serve as a unit measure of volume, the concept of conservation is further emphasized as the child observes a single sample of water as it is placed in differently shaped containers. Since water is a liquid, it takes on the shape of its container. The level, however, varies depending upon whether the sample is placed in a narrow or a wide container. To the child, the water may appear more (taller) or less (shorter). Repeated transfers to the original unit measure should help to develop the concept that the amount of water is really the same. The amount of water is conserved although its shape changes.

In *Activity 5*, the concept of conservation is extended to that of a material other than water. Initially, children observe the different shapes possible with a single piece of clay. The amount, or volume of this piece of clay is then equated with the rise in level when it is immersed in a container of water -- a concept introduced in *Activity 1*. Children observe that manipulating this one piece of material into various shapes and pieces still produces the same rise in water level. The purpose of the activity is to help reinforce the idea of the relation between the piece of immersed clay and the rise in water level, and to use the observation of identical rises to help establish that the amount of material remains the same, no matter how it is shaped. That is, the material is conserved.

In the following activities we return to extending the ideas of selected but arbitrary units of measurement, but instead of volumes, we are now concerned with units of length and temperature. *Activity 6* develops the concepts of measuring linear dimensions -- length, width, or height -- of objects and of the children themselves! Children devise their own units of length. They discover that if these units vary in size, they cannot compare measurements with one another. They gain experience in the selection of a unit and counting repeated units to measure a dimension (replication), the very essence of measurement. They also discover that a larger unit can be thought of as composed of smaller units; that is, they devise their own scales. (In a similar manner they found that large units of volume could be considered as composed of smaller units.)

These experiences provide background for activities in Grade 2, where the commonly accepted scales are introduced, the metric and English systems. It is hoped that their experiences with this activity in Grade 1 will help children to understand that there is nothing magical or preordained about a measuring scale -- but in order to communicate with others a standard scale must be adopted.

In the final *Activity 7*, attention is directed to measuring another property of an object -- its degree of warmth or cold -- identified as its temperature. At first, the children sense the value of this property (its "hotness") by feel. Then, a more reliable and sensitive instrument, an uncalibrated thermometer, is introduced. They should be able to relate the level of the liquid in the thermometer with the degree of hotness, prepare their own temperature scales and use their child-made scales to compare temperatures of objects other than the water samples used in the initial investigation. Thermometry and the use of arbitrary units and scales in thermometry are essential to the upper level of the COPEs curriculum. They are introduced here in Grade 1 without a standardized scale. Starting in Grade 2, when children have a better concept of number line, they prepare a more precise scale of their own, and they are also introduced to the convenient Celsius scale (formerly Centigrade) for all subsequent temperature measurements.

As will be noted in Activity 1: Ordering Objects in Terms of Size, or as it appears in Appendix D, lengthy activities are divided into labeled parts. This activity has seven such parts. Activity 2: Measuring and Estimating Amounts, is also included in Appendix D to show how worksheets are used in helping children learn how to record data.

Assessment materials follow the activities for each topic. Samples of the assessment materials for Topic II: Measurements, are included in Appendix D. Note the detailed manner in which the instructions to the teacher are presented. Also included in Appendix D is one sheet of suggestions for individual assessments having to do with the subject of Measurements.

The following is an outline of the content of the Teacher's Guide for Grade Two:

COPEs: BACKGROUND AND ACKNOWLEDGEMENTS

AN INTRODUCTION TO COPEs

TEACHING COPEs K-2 SEQUENCE

THE K-2 ASSESSMENTS

AN INTRODUCTION TO COPEs, GRADE 2

TOPIC I: WHOLES, PARTS, AND PATTERNS

- Activity 1. Seed and Plant Patterns
- Activity 2. Sounds and Instruments
- Activity 3. Patterns of Sound
- Activity 4. Patterns of Taste
- Activity 5. Patterns in a Magnetic Field
- Activity 6. Patterns of Color

TOPIC I ASSESSMENTS

TOPIC II: MEASUREMENTS, CHANGES, AND PATTERNS

- Activity 1. How Long Is It?
- Activity 2. How Much Does It Weigh?
- Activity 3. Measuring Volume
- Activity 4. Keeping Track of Matter
- Activity 5. Time to Swing

TOPIC II ASSESSMENTS

TOPIC III: PATTERNS AND PREDICTING

- Activity 1. Using Measurement to Show a Pattern
- Activity 2. Prediction and Temperature Change
- Activity 3. Patterns in the Classroom
- Activity 4. Figuring it Out

TOPIC III ASSESSMENTS

MATERIALS AND EQUIPMENT

SCORING GUIDE FOR THE ASSESSMENTS

The following appears in the Teacher's Guide for Grade 2 as an introduction to the teaching materials it contains:

Alice in Wonderland is fun to read but to live for very long in a world that perpetually changes in such strange and unpredictable ways would be very difficult. If every event had to be responded to as though it were totally novel and unlike any other event--that is, if you had no memory or ability to generalize--you would always be venturing into the unknown. It would be impossible to predict the consequences of anything you did.

Science is one human enterprise devoted to making sense out of what might otherwise seem to be a whimsical, magical world. The ways developed by scientists for learning about natural phenomena depend on looking for patterns of relationships among these phenomena. In contrast to a chaotic world where no relationships last beyond a moment, a world in which orderly relationships can be recognized allows one to plan and predict outcomes. The trick is to find the pattern or order.

TOPIC I: WHOLES, PARTS, AND PATTERNS

The children first look for patterns which are visible and relatively stable. They begin with familiar things--seeds and plants--where the spatial relationships between the parts are visible, stable, and well-known to most children. Then they move on to the examination of a pattern of relationships which is somewhat more subtle, namely the association between the length of vibrating objects and the pitch that the instruments produce. But pitch is not something they can see. To detect it, they have to listen to the sound. In Activity 3, the children put sounds together in patterns to form music. Next they

discover the pattern of taste areas on their tongues. They cause common substances like lemon juice, sugar, and salt water to interact with different segments of the tongue and discover that while the tongue looks similar on its upper surface it is really differentiated in its functions: some areas are sensitive to sour tastes, others to sweet, and so on. In Activity 5, the children convert a chaotic or disordered group of particles into visible patterns by allowing iron filings and a magnet to interact. From several such observations, the child may be able to infer that magnets are surrounded by a patterned invisible region--the magnetic field--which is detected by the iron filings. Like the pattern of taste areas on the tongue, the pattern of a magnetic field is not visible unless some kind of detector is used.

That there are often complex patterns hidden from view is also brought out in the final Activity in Topic I. The children produce a series of patterns from a material that looks homogeneous. They take water-soluble inks of different colors and put them on paper toweling which they then moisten. In the process of interacting with the water and toweling, the inks separate into colored components. Furthermore, every time the children repeat the experiment with a given ink the same sequence of colors develops. The pattern revealed by the interaction is repeatable.

TOPIC II: MEASUREMENTS, CHANGES, AND PATTERNS

As the children learn in Topic I, the strategy for finding a pattern in a system is to look for evidences of interaction or to produce interaction in the system. One is aware of interaction only by changes which occur. From the type of changes and where they are occurring, it is possible to infer what the patterns are.

Some patterns of relationships can only be detected by making measurements of the changes going on in a system. That is, one step in detecting dynamic or changing relations is to make periodic measurements of some property or variable, such as size or weight. Such systems change over time, but their way of changing is predictable--there is a pattern to the way in which the change happens. The variables, or properties, one measures depend on what one is trying to find out about the system or the answer being sought to a particular question.

In order to help children understand measurement, they assemble and calibrate their own instruments for measuring length, volume, weight, and time in Topic II. Their experiences with number lines in mathematics will be very helpful in constructing rulers and calibrated containers for measuring volume. To determine weight, the children assemble equal-arm balances; to measure time, they use pendulums.

Measuring instruments allow scientists to keep track of matter and energy in a system. Changes are evidence that something is happening to the pattern of relationships and the measurements indicate what the pattern might be. On the other hand, it sometimes happens that apparent visible changes in a system mask the fact that something else has stayed constant. For example, in Activity 4 of Topic II the children balance equal volumes of cereal against each other. Then they grind up the cereal in one of the cups and find that the system still stays in balance even though the volume of the ground-up cereal is considerably less than the volume of the unground cereal. The grinding changes the volume--the way it packs down--but not the weight of the sample. The equal arm balance allows the children to detect that matter has been conserved. Here an unchanging pattern is revealed by measurement.

TOPIC III: PATTERNS AND PREDICTING

Another level of sophistication in exposing patterns or trends is developed in Topic III. The children construct graphs which are a way of showing orderly relationships when they seem to be masked by sets of complex interactions. Also, sometimes individual events are very peculiar or atypical--you can only find out what the pattern is for a population by examining a large number of cases. Then you have to find some way to organize the data to expose the patterns. Graphs and histograms are means of picturing relationships--of seeing order in what might otherwise seem to have no pattern at all. In addition, they allow predictions to be made--predictions which would not have been possible without imposing order on the data.

In the first Activity, the children measure their head sizes and make a histogram which reveals the range of this property within their population and tells how many of them have the same head size. In the second Activity children detect a pattern of interaction. By using a thermometer to detect temperature changes in a water system to which hot washers are added, they can infer that heat energy can be transferred from one medium to another--that is, from the hot washers to the cold water. A bar graph depicting the effect of adding different numbers of washers to equal amounts of cold water immediately tells the child the general relationship in this interaction--the more washers, the greater the temperature rise in the water. It also allows him to predict what temperature to expect if a still larger number of washers were added.

In the last two Activities, the children look at unordered situations. They find out how long it takes them to do certain things when they work in a disordered classroom as compared with an ordered one. Then they go on to depict the order in the

classroom by making maps of the room, using reference points they have chosen. This theme is developed even further in a series of "card games" where the children find that if they impose an order or pattern on a set of cutouts they can perform certain tasks more efficiently. In this final Activity, the children extend the concepts of graphical representation by allowing positions on a grid to correspond to chosen cards: they select cards from a large collection and represent the sampling with a bar graph which shows the pattern of the selection. The ideas of one-to-one correspondence used in such graphs are basic not only to graphing but to many mathematical operations.

The format of the Teacher's Guide for Grade 2 follows generally that which was adopted for the K-1 Teacher's Guides. However, some changes were made that were considered to add to its attractiveness, readability, and usefulness.

In addition to simple line drawings of diagrams, the artwork includes illustrations of children performing selected investigations within an Activity. These were done by a newly established commercial art group called the "Fat Cats." An example of their work is shown below as an illustration of children experimenting with "Patterns of Sound" (Activity 3, Topic 1) produced by instruments they have made or have brought from home.



These unique characters have become known as the COPES Children and they, or their brothers and sisters, have been used in illustrations in all of the later guides. Blown-up reproductions of some of the COPES Children illustrations have also been used in publicizing COPES. Reactions from teachers, and others, have been highly favorable.

As will be noted from an examination of the second grade Activity included in Appendix D, the design of the pages makes printed materials more readable. It should also be noted that a new item "Allocation of Time" has been included in the activities for the Grade 2 Guide. This was done to help the teacher in planning for each Activity in relation to the rest of her teaching schedule. Also included in Appendix D are three pages of material from TOPIC I ASSESSMENTS. It should be noted that assessment materials for these and other COPES Guides were prepared after all activities for each Topic has been written in final form. Drafts of activities and assessment materials were reviewed by all writing members of the staff.

Teacher's Guides for Grades 3-6

By the time the Teacher's Guide for Grade 2 was completed most of the problems having to do with such technical matters as format, writing style, and illustrations had been settled. The procedure for clearing drafts of materials through writing members of the staff was fairly well established. However, other problems persisted. These had to do with maximizing the use of the laboratory school, reconciling widely divergent points of view regarding the appropriateness of certain activities, selecting clusters of activities that were appropriate subsets in grade sequences, and arranging these clusters into viable sequences for a designated grade level. These and other problems will be discussed more fully in a later section of this report.

Beginning with the Guide for Grade 3, two rather important changes were made. The "skill-phenomenon-concepts" format for reporting teaching objectives was discontinued. This unique feature of the earlier guides was discontinued with great regret since it had proved to be an unusually useful feature of the K-2 guides. However, the process of analyzing activities, defining the objectives, and fitting them into format so that they were intelligible was not only time consuming but required an expertise possessed by only a few key members of the staff. Within the tight schedule that had been established for completion of the remaining guides the time required for them to conduct such analysis could not be accommodated. Some members of the staff are hopeful that in subsequent revisions of these guides it will be possible to complete this important operation for all the guides.

The second change that was made in the guides, beginning with Grade Three, was to refer to each subset of activities within a grade sequence as a "minisequence." The change was more substantial than merely changing the label. Much greater attention was given to the selection and arrangement of the activities that went into each minisequence with the thought that the minisequences might eventually be used alone or in combination with one or more other minisequences as a COPES module in elementary science. This had been done previously with several minisequences from Grades 3 and 4, in developing the module published as The Water Mix Experiments.⁴

The following is an outline of the minisequences included in the Teacher's Guides for grades three through six:

Grade 3

MINISEQUENCE I: THE PARTS OF WHOLES

- Activity 1: Mosaics
- Activity 2: Sieving Soil
- Activity 3: A Very Fine Sieve
- Activity 4: In and Out of Solutions
- Activity 5: Where Did the Green Go?

MINISEQUENCE II: BALANCED AND UNBALANCED FORCES

- Activity 1: Forces: Pushes or Pulls
- Activity 2: Stretching Rubber Bands
- Activity 3: Which Way Will the Paper Clip Move?
- Activity 4: Measuring Gravitational Force
- Activity 5: Weight: A Measure of Gravitational Force

MINISEQUENCE III: AVERAGING AND SAMPLING

- Activity 1: A Fair Share of Peanuts
- Activity 2: A Third Grader's Family
- Activity 3: With the Greatest of e's

⁴ COPES Project, Teacher's Guide Water-Mix Experiments, (Boston, Massachusetts: American Science and Engineering, Inc., 1971).

MINISEQUENCE IV: INTERACTIONS IN ELECTRICAL CIRCUITS

- Activity 1: Finding out about Circuits
- Activity 2: Putting Different Materials in a Circuit
- Activity 3: Putting More Batteries in a Circuit
- Activity 4: Evidence of Battery Interactions
- Activity 5: Heat Energy from Batteries and Wires

MINISEQUENCE V: HEAT ENERGY AND WATER

- Activity 1: The Celsius Thermometer
- Activity 2: Increasing the Temperature of Water
- Activity 3: What Factors Affect a Temperature Increase?
- Activity 4: What Else Affects a Temperature Increase?

MINISEQUENCE VI: INVESTIGATING STARCH

- Activity 1: Two Properties of Starch
- Activity 2: Testing to be Sure
- Activity 3: The Interaction of Starch and Water with Heat Energy
- Activity 4: Parts of Wholes

Grade 4

MINISEQUENCE I CONSERVATION OF MATTER

- Activity 1: The Weight of Melting Ice
- Activity 2: Loss of Weight in an Open System
- Activity 3: Increase of Weight in an Open System
- Activity 4: New Substance, Different Weight?
- Activity 5: "Drying" Apples
- Activity 6: A Bread Mold System

MINISEQUENCE II THE WATER MIX

- Activity 1: Water: A Source of Heat Energy
- Activity 2: Inventing the Heat Energy Unit
- Activity 3: Volume and Heat Energy

- Activity 4: Making Mixes: Water at the Same Temperature
- Activity 5: Making Mixes: Water at Different Temperatures
- Activity 6: Using the h.e.u. to Make Predictions
- Activity 7: A Return to Melting Ice

MINISEQUENCE III: HEAT ENERGY TRANSFER

- Activity 1: Locating Points: Coordinates
- Activity 2: A First Look at a System
- Activity 3: Quantifying the Results
- Activity 4: Where From and Where To?

MINISEQUENCE IV: MOLECULAR SIEVING

- Activity 1: Taking the Red Out of Red Cabbage
- Activity 2: Constructing a Model of a Cabbage Leaf
- Activity 3: Molecules of Different Sizes
- Activity 4: Some Final Observations and Inferences

MINISEQUENCE V: CHANGE OF STATE

- Activity 1: "Disappearing" Heat Energy Units
- Activity 2: Thinking About Solids and Liquids
- Activity 3: Using the Model
- Activity 4: In and Out of the Melt
- Activity 5: Molecules in a Gas
- Activity 6: In and Out of the Gas

MINISEQUENCE VI: USING FREQUENCY DISTRIBUTIONS

- Activity 1: How Many Seeds in a Pod?
- Activity 2: Introducing the Histogram
- Activity 3: How Old are Fourth Graders?
- Activity 4: How Long is a Fourth Grader's Finger?
- Activity 5: Where It Stops, Nobody Knows
- Activity 6: Return of the Pods

Grade 5

MINISEQUENCE I: CELLS: UNITS OF STRUCTURE AND FUNCTION

- Activity 1: Introduction to the Microscope
- Activity 2: Plant and Animal Cells
- Activity 3: Changes Inside Banana Cells

MINISEQUENCE II: DOING SOME WORK

- Activity 1: A Rolling Marble
- Activity 2: What Can A Rolling Marble Do
- Activity 3: What Is "Work"?
- Activity 4: Kinetic Energy
- Activity 5: Potential Energy

MINISEQUENCE III: HEAT ENERGY AND LIQUEFYING SOLIDS

- Activity 1: Melting and Dissolving Solids
- Activity 2: The Disappearance of Heat Energy
- Activity 3: Some Properties of Salt-Water Solutions
- Activity 4: The Reappearance of Heat Energy

MINISEQUENCE IV: ENERGY TRANSFORMATIONS

- Activity 1: Radiant Energy to Heat Energy
- Activity 2: Chemical Energy (Batteries) to Heat Energy
- Activity 3: Chemical Energy (Food) to Heat Energy
- Activity 4: Kinetic Energy to Heat Energy

MINISEQUENCE V: INVESTIGATING POPULATIONS

- Activity 1: Selecting Marbles
- Activity 2: Tossing Cubes
- Activity 3: How Do Thumbtacks Land?
- Activity 4: When Do Seeds Germinate?
- Activity 5: How Do Chemicals Affect Germination?

MINISEQUENCE I INTERACTIONS OF LIVING THINGS WITH THE ENVIRONMENT

- Activity 1 Interactions of Plants and Soil
- Activity 2 Yeast Plants Interact with a Liquid Environment
- Activity 3 Interactions that Produce Carbon Dioxide
- Activity 4 Plants and Water Vapor
- Activity 5 Action in the Underground

MINISEQUENCE II HEAT ENERGY AND HYDRATE BONDS

- Activity 1 Interaction of Heat Energy with Solids
- Activity 2 Water Out and Water In
- Activity 3 The Hydrate Bond
- Activity 4 Using the Model
- Activity 5 Extending the Model

MINISEQUENCE III COPPER: A STRUCTURAL UNIT

- Activity 1 The Shape of Things
- Activity 2 Loss of the Blue
- Activity 3 Copper and Iron Change Places
- Activity 4 Further Corroboration of the Model
- Activity 5 Putting the Blue Back In

MINISEQUENCE IV A TENDENCY TO SPREAD OUT

- Activity 1 The h.e.u. Revisited
- Activity 2 Unavailable for Work
- Activity 3 From Higher Temperatures to Lower Temperatures
- Activity 4 From Higher Concentrations to Lower Concentrations
- Activity 5 A Model of the Transfer
- Activity 6 Transfer Along a Line of Cups
- Activity 7 Transfer Along a Nail

MINISEQUENCE V RANDOM EVENTS: ORDER OUT OF DISORDER

- Activity 1 Diffusion Along a Tube
- Activity 2 Random Walks
- Activity 3 A Trip by Chance
- Activity 4 The Record of a Geiger Counter
- Activity 5 Eye Color in House Flies

MINISEQUENCE VI TOWARDS AN IDEAL MECHANICAL SYSTEM

- Activity 1 The Bouncing Ball
- Activity 2 The Inefficient Pulley
- Activity 3 The Incline Plane
- Activity 4 The Ballistic Pendulum
- Activity 5 A Close Look at a Pendulum

It would appear from the outlines on pages 45-50, that a relatively wide range of subject matter is covered in activities within the 23 minisequences making up the COPEs Curriculum for grades 3 through 6. However, as shown in Table 1, page 51, the activities deal with learning materials contributing primarily to an understanding of the five conceptual schemes that form the framework of the COPEs Curriculum. It will be noted that all conceptual schemes are dealt with at each grade level. Because of the close relationship among conceptual schemes No. 2, No. 3, and No. 4, many of the same minisequences are listed as contributing to two or more of them. To a lesser extent there is overlapping of minisequences contributing to conceptual schemes No. 1 and No. 5 with those contributing to some other minisequences. However, for each of these two conceptual schemes, there is at least one minisequence, at each grade level, that contributes to it in a most direct manner. The minisequences that contribute most directly to a conceptual scheme are underlined in the table.

Sample activities from each of the teacher's guides for grades 3, 4 and 5 are included in Appendix E. In the Grade 3 Activity, "Where Did the Green Go?" children are introduced to chromatography as a means of separating such substances as green food coloring into its components. Also in this activity is a subsection entitled "Extended Experiences." Similar subsections are included frequently in the Teacher's Guides for grades 3 through 6. In all instances they include suggestions of individual investigations which children may undertake in learning more about the subject with which the Activity deals. In the Grade 4 Activity, "Disappearing Heat Energy Units," children apply the principle of the conservation of heat energy in melting ice and discover that heat energy appears to be lost. They then hypothesize that it was used in changing the ice to liquid water. In the Grade 5 Activity, "When do Seeds Germinate?" children discover that you cannot predict with accuracy how long it will take for one seed to germinate. You must, therefore, assume the statistical view in making such predictions for a particular population of seeds.

In the Teacher's Guides for grades 3 through 6, there is an introduction for each minisequence as well as for each Activity within a minisequence. These are designed to help the teachers see how the Minisequence or Activity, as the case may be, is

Table 1 Distribution of Minisequences, Grade 3 through Grade 6, According to Their Contributions to the Five Conceptual Schemes

Conceptual Schemes	Grade 3 Minisequences	Grade 4 Minisequences	Grade 5 Minisequences	Grade 6 Minisequences
No. 1. Structural Units	I The Parts of Wholes VI Investigating Starch	IV Molecular Sieving V Change of State	I Cells: Units of Structure and Function III Heat Energy and Liquefying Solids	II Heat Energy and Hydrate Bonds III Copper - A Structural Unit
No. 2. Interaction and Change	IV Interactions in Electric Circuits II Balanced and Unbalanced Forces V Heat Energy and Water VI Investigating Starch	IV Molecular Sieving V Change of State	I Cells: Units of Structure and Function II Doing Some Work III Heat Energy and Liquefying Solids IV Energy Transformations	I Interaction of Living Things with the Environment II Heat Energy and Hydrate Bonds III Copper - A Structural Unit
No. 3. Conservation of Energy	II Balanced and Unbalanced Forces V Heat Energy and Water	I Conservation of Matter II The Water Mix V Change of State III Heat Energy Transfer	II Doing Some Work III Heat Energy and Liquefying Solids	II Heat Energy and Hydrate Bonds VI The Pendulum
No. 4. Degradation of Energy	IV Interactions in Electric Circuits	III Heat Energy Transfer	II Doing Some Work IV Energy Transformation	IV A Tendency to Spread Out V Random Events VI The Pendulum
No. 5. Statistical View	III Averaging and Sampling	VI Using Frequency Distributions	V Investigating Populations	V Random Events IV A Tendency to Spread Out

related to the whole of which it is a part and, more particularly, to what preceded it. They were also designed to give the teacher an overview of what is to be dealt with in either the Minisequence or Activity. For these reasons the introductions are considered to be a critical part of the teacher's guides and a great deal of care has been exercised in preparing them.

For the Teacher's Guides from grade 3 through 6, the assessment materials were prepared in much the same manner as those for earlier grades. Included in Appendix E are samples of the materials as they appear in these guides. The Grade 3 sample assesses concepts to be developed in a minisequence dealing basically with the Statistical View of Nature. The Grade 4 sample deals with concepts that are primarily related to Conservation of Energy and the Grade 5 sample deals with Structural Units. It should be pointed out here that all instructions to children and all assessment items are to be read aloud by the teacher when the assessments are administered. This is done to minimize the effect of reading ability upon accomplishment of the assessment items.

CHAPTER IV

PROBLEMS

A number of the problems encountered by the Project have been referred to briefly in earlier chapters of this report. With reference to personnel, these problems had to do with recruiting qualified persons, helping the newly acquired ones to understand the Project's goals and to become committed to their accomplishment, and finally, maintaining good working relationships among the Project's staff. Other problems dealt with substantive matters related to the production of an elementary science curriculum based upon a conceptual scheme approach. These included the production of teaching materials that were relevant to the five conceptual schemes and appropriate for elementary school children. The more substantive problems also included evaluation of the COPES curriculum materials and their dissemination. In some instances the personnel problems and the substantive problems were so inter-related that it is not possible to discuss them separately.

Personnel

In the early planning for the Pilot Phase, it was recognized that the Project would need competent scientists, not only as advisers and/or consultants but as day-to-day workers. Knowledgeable science educators, psychologists, and classroom teachers would also be needed. It was agreed that maximum use should be made of the New York University faculty wherever both qualified and willing professors could be identified. This was to be done in order that the Project would become, in fact, an all-University effort, rather than merely a pet project of one or two University professors. This was in keeping with the fact that science education at New York University had been recognized, for a number of years, as an all-University responsibility. For these reasons staffing of the Project was initiated by recruiting University personnel. The Project director, a physicist, and the associate director, a science educator, were the two University professors who had initiated the Project. All four of the original permanent consultants were University scientists, each of whom was chairman of his respective department. The psychologists and two additional science educators were also University professors. Since all professors had other institutional commitments it was impossible to obtain their full-time participation on the project. However, it had been recognized that a staff made up entirely of part-timers could not sustain the continuity of effort that would be

needed by a project of the magnitude of COPES. Some full-time key staff people were needed. It was generally agreed that one should be a qualified scientist, who was favorably predisposed toward curriculum work in elementary science, and the other should be a science educator who was similarly predisposed.

In the early stages of our search it was confirmed that the kind of scientist and science educator we were looking for already had responsible positions in collegiate institutions and therefore, were not interested in taking a leave of absence for the extended period that they would be needed. Several were interested in two-month summer stints with COPES, but we were after at least a two-year full-time commitment. Eventually an interested scientist, who had been in industry for a number of years, was located. She had expressed a desire to leave industry and return to an academic community. The challenge of the COPES Project appealed to her. She was employed and began work with the Project in January, 1966. Within a short time after becoming associated with COPES, she distinguished herself as a scientist who had much to contribute to the Project and as one who could provide the continuity of effort which was to become so crucial to the success of the Project. She was later made assistant director of the Project.

During the Pilot Phase, the two science educators associated with the Project on a part-time basis were both specialists in the teaching of elementary school science. In addition two graduate students in science education were employed full-time by the Project, however both were specialists in the teaching of the physical sciences at the secondary school level. In the beginning it was not possible to obtain the services of a qualified psychologist, for either part-time or full-time participation. Therefore, we had to settle for the consultant services of one University psychologist. She was also an evaluation specialist. Four elementary science teaching specialists from the public schools were added to the staff as summer participants. Eventually, a graduate student from educational psychology joined the staff to assist with the technical aspects of the evaluation effort involved in the Pilot Study. Throughout, the Project has had the services of at least one full-time secretary.

In addition to the permanent core of four consulting scientists mentioned earlier, additional scientists, science educators, school administrators and educational research specialists have been used as consultants when the need for such services was indicated.

The Project has also maintained an Advisory Committee made up of from ten to twelve active members. Membership of the committee has consisted of prominent persons from outside the University, including scientists, school administrators, psychologists, a philosopher, a science supervisor, and a dean of a well-known school of education.

To summarize, the following personnel have been associated with COPES at one time or another during the active Phase of its development:

Scientists	20
Astronomers	1
Biologists	3
Chemists	7
Geologists	2
Meteorologists	1
Physicists	6
Science Educators	5
Psychologists	5
Dean	1
Philosophers	1
Mathematician	1
Editors and Assistant Editors	5
Secretaries	8
Docotral Students in Science Education	12
Undergraduate Assistants	12
Science Teaching Specialists	6
Laboratory School Teachers	4
Public School Superintendents	2
Elementary School Principals	12
Elementary School Teachers	<u>30</u>
TOTAL*	124

*Plus 75 Laboratory School Children

Scientists

In terms of recruitment of personnel for the Development Phase, our most difficult problem was to find two or more additional scientists who would work on the Project full time. Since we had previously been successful in locating such a person in industry, we turned again to that source and were successful in locating another Ph.D. chemist. She joined the staff in the fall of 1969. A second scientist, a Ph.D. biologist, was located through the University as a recent graduate from the biology department. He too joined the staff in the fall of 1969. It had taken us almost a year to fill these two positions, thus shortening the period of the scientists' potential effectiveness within the limited time in which the Project was expected to complete its mission. Several factors contributed to the delay. Even though the Project was scheduled to get under way in September, 1968, the official notification regarding the award of the grant was not received until February 1, 1969. Until the grant was official one could not recruit with any guarantee of employment. Then too we had learned through our three years of experience that it took something more than just being a scientist to produce what we were after. We were looking for a special breed of scientist, and they were not easy to locate.

We entered the second year of the Development Phase with three full-time scientists - two chemists and a biologist. Everyone was hopeful that the production of the scientist membership on the Project would be greatly enhanced. However, it did not happen entirely as had hoped. Within a few months it became evident that one of them was not producing as had been anticipated. This scientist was well trained and had demonstrated aptitudes of creativity, however, after two or three rather bright beginnings, there was a noticeable loss of interest and drive. Although repeated efforts were made to help this person adapt to the tasks at hand and the working procedures that had been found to be effective the situation became progressively worse. It was therefore necessary to release this scientist after almost a year's unproductive association with the Project. Why wait a year in such a case? For one whose training was rigorously scientific and whose experience had been restricted to research, it was anticipated that it would take at least a month or so to become thoroughly acquainted with the COPES philosophy and our manner of work. It was expected that additional time would be needed for the person to create one or more appropriate activities. Once this had been accomplished, it would take additional time to learn how to write clearly in ways that the average elementary school teacher could comprehend. For these reasons it took some time before the directors were convinced that, what appeared to be, a competent scientist could not produce what was needed on this Project.

We have reported at some length about this one case because there were other instances where we employed people who could not perform the duties for which they had been employed. In all such cases conscientious efforts were made to give them the encouragement and the assistance which appeared to be so needed. However, in some cases it did not work out. Their time, as well as the time of those who were responsible for their supervision, constituted an irretrievable loss to the Project. We had learned something from the Pilot Study regarding the sorts of persons needed to perform the various tasks; we were not operating in the dark. In retrospect it would appear that in selecting some personnel we should have been more deliberate. We should have insisted upon demonstrated acceptable performance before making a commitment for longer than one month at a time.

It may appear that we should have attempted to bring scientists to the project who had had experience in working in other science curriculum projects. We did obtain the services of two, but only on a part-time basis. One appeared to be quite at home in dealing with curriculum matters but had so many other irons in the fire that both the quality and quantity of his production for COPES was unimpressive. The other had been most successful in working upon a science curriculum project for undergraduate college students. He made a number of excellent contributions to COPES, however, he had difficulty in writing at a level suitable for the average elementary school teacher. All scientists on the Project experienced this difficulty to a greater or lesser extent and much of their "good stuff" had to be rewritten.

There were other scientists who applied for positions with COPES but who, for various reasons, were not considered to be qualified. The most common disqualifying factor was their deep commitment to other "pet" ideas about science teaching. To re-train such persons was considered to be beyond the purposes of this Project.

Science Educators

Other than two doctoral students, all science educators on the Project were either part-timers or worked for varying periods of time as consultants. The experienced science educators on the Project were initially no more at home with a conceptual scheme approach to elementary science than were the scientists. Most of the science educators had been professionally active during a period of curriculum development in science where science generalizations, or principles of science, were considered to be worthy goals toward which science instruction should be directed. But, as Barnard has pointed out, the two approaches are quite different.¹

¹J. Darrell Barnard, "The Conceptual-Scheme Rationale in Science Education," New York University Educational Quarterly, II: 24-30, Spring, 1971.

In the science-principles approach there was a two-pronged emphasis. One was to develop some understanding of a relatively large number of science principles. The other was to apply them to problems of human welfare. Ultimately the emphasis, by the principles approach was on applied science. The conceptual-scheme approach as it was used in the COPES Project, emphasizes understanding of the relevant science as the ultimate goal. Applied science is of no immediate concern in such a curriculum effort.

Some of the science educators had also been conditioned to a more loosely structured program of science for the elementary school than COPES was destined to become. COPES had been conceived as a highly structured program and efforts to make it otherwise were to be avoided. At least one of the science educators viewed elementary science as a series of activity episodes involving such topics as heat, electricity, living things, machines, and the like. This person had gained recognition for demonstrated abilities to devise activities within this context.

All of the science educators had taught children and had a fairly good sense of what children could do with the kind of science the educators had promoted. Two of them had had extensive experiences in writing science textbooks for children. However, none of the science educators possessed sophisticated understanding of the science underlying each of the conceptual schemes. The scientists were expected to supply this dimension of understanding for the Project and share it with the science educators. The science educator was expected to supply the practical educational dimension, even though the project was conceived in a context of science within which none of them had worked before. This became a major adjustment for the science educators to make. In fact one of them dropped out after participating for one semester in the Project.

Psychologists

Other than four graduate students from the Department of Educational Psychology, there were never any full-time psychologists associated with the Project. For the most part the graduate students were involved in matters having to do with evaluation. These had to do with adapting the Structure-of-Intellect aptitude inventories to elementary school children, developing concept tests for use in the Pilot Study, and developing assessment materials for use in the Teacher's Guides.

The new chairman of the Department of Educational Psychology joined the COPES staff during the summer of 1969 on a part-time basis. As mentioned earlier he assumed responsibility for developing the COPES Evaluation Plan. He recruited graduate students to perform certain functions within the plan and supervised their work. He designed the format for assessment materials and worked closely with those who prepared the items for each set of materials. He prepared the grand design for broad field testing of COPES teaching materials. His expertise in Guilford's theory of the

Structure of Intellect was used, appropriately, in the development of the COPES Evaluation Plan.

Some graduate students in psychology came into the Project with their own research interest fairly well crystallized. This meant that their interests often had to be sublimated and/or adapted to the tasks at hand. For some the adaptation was made to the clear advantage of the Project.

In retrospect, if the Project had had, from the beginning, the services of the psychologist who joined its staff in the summer of 1969, it would have benefited greatly. The major benefit would have come from having the COPES Evaluation Plan as a theoretically definable context within which the Pilot Study would have been conducted. But we were unable to find such leadership in evaluation until we had been in business for more than three years. Even though we might have located this person, prior to his joining the faculty at New York University, would he have been interested and/or available in joining COPES full-time? Probably not.

Editorial

The problems of editing the COPES Teacher's Guides were legion. One of the most difficult problems was rewriting materials that had been prepared by many members of the writing team. Often the material had to be rewritten in a reasonably acceptable style. This generally took a good deal of the editor's time, or the time of some other more experienced writer. The rewritten material then had to be approved by the original writer to insure that the meaning and content had not been inadvertently altered. Sometimes the process of negotiating editorial changes took considerable time and turned out to be an unpleasant experience for both parties.

A second problem of major importance was that of selecting the activities and arranging them into viable sequences. In COPES this was generally done by certain members of the staff working with the editor. In the process, materials, upon which a writer may have spent considerable time putting together, had to be discarded. Obviously some resentment developed. On the other hand when a sequence was being put together it may have been discovered that one or more additional activities were needed to fill in gaps. Someone had to assume this responsibility, often at a time when he might already have been deeply involved in other writing.

A third problem had to do with getting proper introductions and other front material written for each of the sequences. These could be written only by one who had a thorough overall acquaintance with both the science and the pedagogical features of the sequence. The director and/or the assistant director usually assumed this responsibility.

A fourth problem was to encourage the psychologists to complete the assessment materials in time to avoid publication delays. Deciding upon what art work was to be done and getting it completed on time constituted a fifth problem. Then came the job of carefully editing all of the material and getting camera-ready copies of it typed. Finally, there was the problem of making the necessary arrangements with the printer.

If the above review is not convincing that editing the COPES guides was a demanding task then a more detailed account of the many specific tasks involved in each problem would surely be. It was not until we had lived through the accomplishment of these tasks in getting out The Teacher's Guide for the Conservation of Energy Sequence that we fully appreciated the complexity of the editorial job.

We were fortunate in obtaining the full-time services of a doctoral student in science education, during the second year of the Pilot Study, who assumed the duties of an editor. His good work is clearly demonstrated in The Teacher's Guide for The Conservation of Energy Sequence. He also edited the Final Report of the Pilot Study, A Pilot Project to Develop an Elementary Science Sequence. An unsuccessful effort was made to get him to stay with the Project indefinitely. However, he did stay for the interim year, during which time he completed his doctorate, and then left the University for another position.

For the interim year, one of the science educators assumed responsibility for editing A Preliminary Teacher's Guide for a Tentative Sequence of Activities Developing The Statistical View of Nature. This too turned out very well from an editorial point of view.

Persistent efforts were made to obtain the services of a full-time professional editor for the grade level Teacher's Guides to be produced during the full Development Phase. A number of prospects were considered and one person was employed, who turned out to be unsuitable. Errors in judgment were made because we had not insisted upon demonstrated editorial competence before employing her. We were overly eager to get an editor on the job during the time that basic materials were being written in the hope that we might avoid unnecessary duplication of work later.

One of the science educators assumed responsibility for editing first-draft editions of the K-1 and Grade 2 guides. However, it was eventually decided that a commercial agency would be given the job of editing the final drafts of K-1 and 2. Most of the agency's editorial work turned out to be merely copy editing and was done in its offices without necessary consultation with the COPES staff. As it turned out, we were not satisfied with the agency's work, and we renewed our search for an in-house editor. Fortunately we found someone who had served as an editor on some of the supplementary materials for the Time, Space, and Matter

Project. She took over the Teacher's Guide for Grade 2 and has done an exceptionally good job of editing all subsequent guides. At one time she had a part-time assistant. However, the part timer had so many other commitments that she failed to work out as well as she was capable of doing.

Secretarial

Someone has said that "as goes the principal of an elementary school, so goes the school." It might also be said that "as goes a project secretary, so goes the project." The secretary is the one member of the staff who has most frequent contact with persons inside, as well as interested persons outside the project. Thus she can do more than any other staff member to promote good relations in or out of the project. She knows more about the production and maintenance of the paper work of the project than any other person. In fact, she is probably better acquainted with the idiosyncrasies of persons associated with the project than anyone else. Both her competence and her commitment are extremely important to the smooth operation of the project.

We have had a succession of eight secretaries over the seven years that COPES was in its Pilot and Development phases. On one end of the spectrum we have had a secretary who was ideally suited for her work and delivered accordingly. On the other end of the spectrum we have had secretaries who, although technically competent, were emotionally unstable and irresponsible persons. One of the problems which a project such as this one is faced with is its dependence upon "soft" money for continuation from year to year. Since secretaries have no assurance of permanent employment, we could not attract persons who aspire to long-term employment. One may argue that such a situation also has its advantages, in that there are many competent people who are looking for short-term, good-paying positions. However, it would appear that the disadvantages outweigh the advantages.

It should be mentioned here that other departments in the University, particularly the Department of Science Education, contributed secretarial assistance to COPES whenever such assistance was needed.

Laboratory School

As was reported earlier, the COPES laboratory school was maintained over a period of three years and used to try out activities before they went into the guides. During the three-year period there were six people who served as laboratory school teachers. Their salaries represented the principal cost of the laboratory school. This was relatively small except for the last two years of the school's operation. It is estimated that the laboratory school cost the Project approximately \$50,000 to operate over the three-year period. The consensus is that it

was well worth it. Its principal advantage was that children were readily available when needed in checking the suitability of materials as they were prepared. In nearby schools, that had been used on occasions when the laboratory school was not operating, both children and teaching conditions were more typical. However, the children were not always available at times when they were needed.

The laboratory school did a great deal to acquaint New York University faculty with COPES. Especially was this the case for those faculty members who had children in the school. In terms of promoting COPES as a cooperative venture with children, the laboratory school has been an attractive feature.

Evaluation

As mentioned earlier evaluation had been a persistent problem with COPES. An overall design for evaluation was developed by the Project's evaluation specialist (see page 20). As will be reported in the research section of this report, several studies have been conducted which not only demonstrated the feasibility of his design but also that such an effort for COPES in a Field-Testing Phase would be highly desirable.

Two different proposals for field testing have been submitted to the Office of Education, the first on April 15, 1971. Both were rejected. More recently a third proposal was submitted to the National Institute of Education; it too was rejected. Through the Publishers Alert Service, retained by the Office of Education, all publishers have been contacted who might be interested in eventually publishing the COPES materials. The Alert emphasized a field-testing proposition as a prerequisite to publishing. No publisher was interested because of the cost of field testing.

At this point in time it would appear that we are going to have to give up the idea of broad field-testing of COPES materials.

Dissemination

Many efforts have been made to keep schools and colleges across the country informed about the nature of COPES and its progressive development as a curriculum. This was done through articles written about COPES and/or the conceptual scheme approach. (See bibliography in Appendix F.) It was also done through a series of COPES Newsletters (see copy of No. 4 in Appendix F), and a 16-page COPES brochure that was periodically brought up to date through a series of revisions during the Development Phase. COPES has maintained an exhibit, and a dissemination center, at every national meeting of the National Association of Science Teachers Association since 1967. It has also maintained such dissemination efforts at several of the Association's regional meetings. The format of the exhibit

has been completely changed four times, not only to improve its attractiveness but to keep it up to date. We have conducted more than 100 workshops from the Puget Sound Area in the Northwest to Georgia in the Southeast. Materials dealing with COPES have become a part of The Elementary Science Information Unit distributed by Technicon Education Systems.¹ At the time of this report we have more than 8,000 names on our mailing list. When each teacher's guide was published it was announced in an attractive flier, such as those shown in Appendix F. These were sent to all names on our mailing list. As will be noted the flier also includes a form to be used in ordering copies of the guides.

During the interim year (1968-1969) a physical science course, based upon the conceptual scheme approach was offered for elementary school teachers by two members of the COPES staff through New York University at Plainedge, Nassau County, New York. Financial support for the course was provided by the National Science Foundation under its CCSS Program. Fifty teachers satisfactorily completed the course which met one evening a week for 30 weeks.

The course had two main objectives. One was to upgrade the science backgrounds of teachers so that they would be more competent to teach the various new elementary science curricula. The other objective was to test the feasibility of the conceptual scheme approach for an in-service course by determining whether a group of teachers, exposed to such a course, could then handle the COPES curriculum in their classrooms.

The basic outline for the course was derived from the Conservation of Energy Sequence developed and tested in the Pilot Study.² However, the science content of the syllabus was extended substantially both in depth and breadth to provide teachers with a broad but integrated experience in physical science.

The results of periodic tests, write-ups of laboratory work, reactions during discussion periods and written reactions on questionnaires indicated that these teachers became progressively more competent to deal with increasingly sophisticated concepts. Both scientists and educators, who worked with and observed the teachers, noted that an unusually high order of interest was maintained throughout the term of the course. Approximately one-half of the teachers introduced COPES teaching

¹Technicon Education Systems, 580 East Middlefield Road, Mountain View, California 94040.

²The Teacher's Guide for a Conservation of Energy Sequence, COPES Project (New York: New York University, August 1967). Morris H. Shamos and J. Darrell Barnard, A Pilot Project to Develop an Elementary Science Sequence, United States Office of Education Project No. H-281 (New York: New York University, 1967).

materials in their classes during the progress of the course.

Twelve elementary schools, in which 26 of these teachers were located, were visited by the associate director of the Project during the second semester of the inservice course. He found that these 26 teachers had generated a good deal of enthusiasm for science in their respective schools. Much of the enthusiasm had grown out of experiences that the teachers had when using the COPES materials in their classes. The materials had been used in classes with children ranging in ability from the nonreader to the gifted.

In terms of enthusiasm and interest there is no question but that the COPES program had captured the imagination of this group of elementary school teachers. In the four years subsequent to this course 25 of the teachers have maintained a close relationship with the Project and have used their classrooms to try out new COPES activities whenever such service was requested by the COPES staff. Furthermore, this experience has demonstrated the effectiveness of such an inservice course for teachers in disseminating COPES.

The pamphlet, Water-Mix Experiments, was published and distributed by American Science and Engineering.³ This was done with the idea of getting some COPES materials on the market ahead of the time that all of its preliminary editions of teacher's guides would be published.

In 1969 the U.S. Office of Education, under the Education Professions Development Act, funded a two-year project at New York University for the Training of Teacher Trainers with emphasis upon elementary school science and mathematics. One of the purposes for designing the New York University effort with a major thrust in elementary school science was "to take full advantage of the presence of the COPES Project..."⁴

In 1971 this project, with an overriding goal to upgrade present programs for prospective elementary school teachers in science and mathematics education at New York University, was funded for an additional two years. Thus the Training of Teacher Trainers (TTT) Project at New York University extended over a period of four years, during which time a close working relationship developed between it and the COPES Project. A number of mutual advantages were realized by the two projects. To a large extent these advantages were made possible by the fact that the associate director of the COPES Project was also the science education coordinator for the TTT Project.

³COPES Teacher's Guide: Water-Mix Experiments, American Science and Engineering, Education Division, 20 Overland Street, Boston, Massachusetts, 02215.

⁴From the proposal for a TTT Project submitted to the Office of Education by the Project Director, Professor George Manolakes.

Several categories of participants were involved in the TTT Project. They included: college students who were being prepared to become elementary school teachers, elementary school teachers and science coordinators in cooperating schools, paraprofessionals in the cooperating elementary schools, selected predoctoral fellows who were enrolled in full time graduate programs to prepare them to become teacher trainers (TT's) in elementary school science or in elementary school mathematics, and postdoctoral fellows who held responsible positions as teacher trainers in their home institutions.

There were several ways in which the COPES and the TTT Projects interacted. COPES teaching materials, along with teaching materials from other elementary science projects, were used in informal workshops and regularly scheduled University classes in the teaching of science for prospective elementary school teachers, paraprofessionals, and teachers. COPES workshops were conducted for both the predoctoral and postdoctoral fellows during which the similarities and differences between COPES and other programs were discussed. The COPES library was frequently used by all science education fellows. Members of the COPES staff gave freely of their time to confer with predoctoral students whose research dealt with COPES materials.

Over the four years there have been three classes of postdoctoral fellows in science education with a total of 17 persons and two classes of predoctoral fellows in science education totaling 11 persons. During the time they were at New York University an effort was made to prepare both predoctoral and postdoctoral fellows to serve as representatives of COPES when they returned to their home institutions.

An example of how one postdoctoral fellow followed through in his home institution with COPES materials is the case of a professor from the State University College at Geneseo, New York. His report entitled, "Some Reactions of College Students to Classroom Use of COPES Materials" is included in Appendix F. Six of the eleven predoctoral participants of the TTT Project have conducted doctoral studies in which their research dealt with COPES teaching materials. A review of their research is included in the following chapter of this report.

From a review of the above, it would appear that we have done a good job of disseminating COPES during its Development Phase. However, we have not been happy about our inability to accommodate all of the requests for COPES workshops. This has not been possible due to limited staff and lack of funds for such activities. After the fourth edition of our Newsletter we had to discontinue publication, also for lack of funds.

In retrospect we should have anticipated the need for greater dissemination activity and provided for it in the budget we submitted for the Development Phase. On the other hand, if this had been done it might have put the budget for the Project beyond the upper limits for favorable consideration by the Office of Education.

CHAPTER V

RESEARCH STUDIES DEALING WITH COPEs MATERIALS

Investigations of Achievement Tests Used in the Pilot Study

From the beginning of the Pilot Study certain members of the staff were concerned primarily with assessing the achievement of children who were taught with the COPEs Conservation of Energy materials. Although the teaching materials involved children in the processes of investigation, the primary objective was concept development. Thus the task of evaluation included the development of testing materials to assess children's understandings of the concepts with which the sequence dealt. Two tests were developed.

One Test, The COPEs Test of Critical Terms, deals with terms considered to be critical to the understanding of concepts in the Conservation of Energy sequence. These concepts can be represented by words such as speed, melt, solid state, balanced, kinetic energy, evaporates, and work. The test consists of 46 items, 32 of which are picture items and 14 of which are sentence choices. A copy of the test and an account of how it was developed are included in the final report of the Pilot Study.¹

The second test, The COPEs Test of Science Concepts, deals with ten major concepts developed in the Conservation of Energy sequence of teaching materials. To assess children's understandings of the major concepts, Suchman's Predict-Control-Explain test model was used.² The test consists of ten problem situations, each of which has three multiple-choice items: one item has to do with making a prediction; another item deals with controlling some action in the problem situation; and the third item involves an explanation for the prediction and the control. Thus the entire test contains 30 test items. A copy of the test and an account of how it was developed are also included in the final report of the Pilot Study.

During the Pilot Study The COPEs Test of Critical Terms was administered in 14 (K-6) classrooms involving approximately 350 children. The COPEs Test of Science Concepts was administered in eight (3-6) classrooms involving approximately 200 children.

¹Morris H. Shamos and J. Darrell Barnard, op. cit., Appendix E.

²Richard J. Suchman, The Elementary Science Training Program in Scientific Inquiry, University of Illinois, 1961. U.S. Office of Education Project No. 216.

In one-half of these classrooms, children were taught the COPES Conservation of Energy sequence and in the other half they were not. Conclusions that the Pilot Study was successful were based, in part, upon comparisons of test results from the two treatment classes. Two of the graduate students employed by COPES during the Pilot Study performed analyses of these tests for their doctoral research.

Shah, a graduate student in educational psychology, investigated the validity of The COPES Test of Critical Terms and the COPES Test of Science Concepts.³ He found that: 1) Test items discriminated better than by chance, 2) Test items could not be demonstrated to constitute a scale, such as a Guttman Scale, 3) Criterion-related validity of the tests can be demonstrated, 4) The higher the concept in the hierarchy of science concepts in the conceptual scheme under investigation, which an item in The COPES Test of Science Concepts is intended to measure or represent, the more difficult, on the average, the item will tend to be.

Woodruff studied the relative effectiveness of the COPES Test of Science Concepts in assessing children's concepts.⁴ Children's concepts were assessed by an oral interview technique and compared with an earlier assessment of the same concepts by The COPES Test of Science Concepts. All assessments were administered after the children had been taught the lower level of the Conservation of Energy sequence, which had been used in the Pilot Study. He found that in many instances, children could explain concepts which the results of the COPES written test indicated they did not possess. Children often found the vocabulary and the sentence structure of the written tests to be too complex, even though all test items had previously been tried out with children and revised before they were used in the Pilot Study. The results of Woodruff's study clearly indicated the need for some less elaborate approach to the assessment of concepts. Our new evaluation specialist came into the Project at the time Woodruff was completing his study. As was reported earlier, he developed a less complex approach to the assessment of concepts than that used in the Pilot Study.

³Rashid Ahmed Shah, "The Structure and Criterion-Related Validity of the COPES Test of Critical Terms and the COPES Test of Science Concepts," (Unpublished doctoral thesis, New York University, 1969).

⁴Bobby J. Woodruff, "The Assessment of Certain Concepts Held by Selected Children Using Individual Interviews and The COPES Test of Science Concepts," (Unpublished doctoral thesis, New York University, 1969).

Investigations of Children's Aptitudes
as They Relate to Learning COPES Materials

The "Proposed System for COPES Evaluation," presented previously on page 20, called for a plan whereby factors such as children's aptitudes, previous learning, and cognitive style would be studied in relationship to their learning via COPES teaching materials. Several aptitude studies have been conducted under the supervision of the COPES evaluation specialist, who is a scholarly proponent of Guilford's Structure-of-Intellect Theory.⁵ In Sher's study, aptitude measures based on Guilford's Structure-of-Intellect model were developed for elementary school children.⁶ These were then used to study the mediation of achievement by children's abilities in third and fourth grade classes which studied the thermal energy portion of the COPES Conservation of Energy sequence. The study of children's learning as a function of the inservice training of their teachers, and of the learner's aptitude, disclosed the statistically significant contributions of aptitudes in the domain of productive thinking about both figurally- and verbally-mediated ideas.

Sher's study was followed with one conducted by Ukens, a predoctoral fellow in the New York University TTT Project.⁷ Ukens investigated the relationship of certain SI abilities to pupil achievement in the mechanical energy segment of the COPES Conservation of Energy Sequence. Scores on 21 SI tests covering 17 different abilities were determined for a sample of 158 sixth grade pupils in two suburban Baltimore County, Maryland schools. A pretest based upon selected mechanical energy concepts, those prerequisite to the sequence, was administered to the same sample. The COPES materials for mechanical energy were then taught by the teachers in their respective classes. The teachers had previously been given inservice preparation using the COPES materials. A posttest based upon the concepts taught in the sequence was then administered.

The data were compiled with means and standard deviations being determined and a correlation matrix between all 23

⁵J. P. Guilford, The Nature of Human Intelligence (New York: McGraw-Hill Book Co., 1967), p. 60.

⁶Abigail B. Sher. "Using Aptitude Measures as Predictors of Differential Achievement." (Paper presented to the AERA Convention, New York City, February 4, 1971.)

⁷Leon L. Ukens. "The Relationship Between Certain Structure-of-Intellect Abilities and Achievement in a Selected Sequence from the Conceptually Oriented Program in Elementary Science." (Unpublished doctoral thesis, New York University, 1972.)

variables was then constructed. An analysis of the data was performed using a stepwise multiple regression analysis with the posttest scores serving as the dependent variable. For the total sample, convergent production of semantic relations (NMR), convergent production of symbolic relations (NSR), convergent production of figural transformations (NFT), and divergent production of semantic transformations (DMT) were found to be significant predictors of achievement on the posttest.

Chemical bonding, another segment of the COPES Conservation of Energy Sequence, was investigated by Keller.⁸ He was also a predoctoral fellow in the New York University TTT Project. Keller's study followed a design similar to that used by Ukens. He hypothesized that the prediction of posttest achievement using pretest achievement and selected SI scores would be greater than prediction from the pretest alone. The subjects of his study were 150 children in five fifth grade classes in Public School No. 41, Manhattan, New York. A pretest based upon selected thermal energy concepts, those prerequisite to the heat-energy, chemical-bond sequence, was administered to all subjects after the corresponding prerequisite activities had been taught. The teachers who taught these classes had been given inservice preparation by Keller. Scores on 12 SI tests, covering 13 different abilities were obtained for all of the 150 subjects. The heat-energy, chemical-bond activities were then taught and a posttest, based upon concepts in those activities, was administered.

Multiple regression coefficients were derived from the pretest and the significant SI predictors for the total sample and for the two subsamples of boys and girls. Convergent production semantic relations (NMR), convergent production figural transformations (NFT), divergent production semantic transformations (DMT), cognitive semantic relations (CMR), and cognitive semantic classes (CMC), were found to be significant predictors. Thus the results of Keller's study sustained his hypothesis that prediction of posttest achievement, involving chemical-bonding concepts from COPES, using pretest achievement and selected SI scores will be greater than prediction from the pretest alone.

All three of these studies (Sher, Ukens, and Keller) dealt with segments of teaching materials within the COPES Conservation of Energy Sequence. Sher investigated a fourth grade segment, heat energy in water mixes; Keller investigated a sixth grade segment,* heat energy and chemical bonding; and Ukens investigated a sixth grade segment, mechanical energy. Each found that selected SI abilities are predictors of achievement in the Conservation of Energy Sequence as it is developed at

⁸Elhannan L. Keller, "The Relationship Between Selected Structure-of-Intellect Abilities and Achievement on Fifth Grade Students in a Sequence of Science Activities that Develop the Concept of Molecular Bonding." (Unpublished doctoral thesis, New York University, 1973.)

*However, it was taught satisfactorily at the fifth grade level.

each of the upper three grade levels. It is anticipated that similar studies dealing with concepts related to the other conceptual schemes will produce comparable results. Therefore, the evidence produced by these and similar studies should provide a broader base for making decisions regarding the sequencing of activities in revised editions of COPES. The evidence should also make it possible to inform teachers regarding what SI abilities children must have in order to be successful in the COPES curriculum.

Investigations Related to Teacher Education

It was reported earlier on page 63 that, in 1968, two members of the COPES staff conducted a one year off-campus science course for approximately 50 elementary school teachers. The course was based upon The Teacher's Guide for a Conservation of Energy Sequence. Each session included a lecture followed by two hours of laboratory work during which time teachers performed the activities in the Teacher's Guide. The laboratory work was usually followed by a directed discussion of how teachers could use the materials, with which they had been working, in their own classrooms. Toward the end of the course 25 of the teachers were visited in their schools by a third member of the COPES staff. Based upon the data he obtained during these visits, it was reported that a single concept science course, with laboratory, is highly effective in developing a commitment to teach science, skill in working with children, and a general awareness of the nature of science.⁹

Based upon the above, Graeber, a predoctoral fellow in the TTT Project, hypothesized that if teachers are to use an inquiry-discovery approach in their teaching, the science methods course for prospective elementary school teachers should be based upon the development of one important concept of science and should itself be taught using an inquiry-discovery approach.¹⁰ In her study Graeber compared a typical "overall" approach to the teaching of science methods courses for prospective elementary school teachers with an experimental approach based upon the COPES rationale. The experimental approach concentrated upon activities as prescribed in The Teacher's Guide for a Conservation of Energy Sequence and taught exclusively by involving prospective teachers in the same type of investigations recommended for use with children. The positive statistically significant difference in favor of the experimental group, obtained through testing the teaching performance of students involved in the study, supported the investigator's hypothesis. The experimental approach, as used in this study, was not only effective in developing positive teacher attitudes toward teaching science but also positively affected actual teaching performance.

⁹J. Darrell Barnard, "The Conceptual Scheme Rationale in Science Education," New York University Education Quarterly, Vol. II, No. 3, Spring, 1971, p. 28.

¹⁰Mary Graeber, "A Comparison of Two Methods of Teaching an Elementary School Science Methods Course at Hunter College." (Unpublished doctoral thesis, New York University, 1971.)

An Investigation of an Audio-Tutorial Approach to Teaching Selected COPES Activities

In the early days of COPES, all-University faculty seminars were held as a means of acquainting the N.Y.U. faculty with the goals of COPES and how we proposed to achieve them. At one seminar in which the highly structured nature of COPES teaching materials was discussed, a professor, who was interested in programmed learning, became enthusiastic about the prospects of adapting the COPES teaching materials to a programmed-learning approach to elementary school science. Thus we were conditioned to be on the lookout for a graduate student, who might be interested and capable, to conduct a feasibility study using selected activities from COPES. With encouragement from members of the COPES staff, Netburn, another predoctoral fellow in the TTT Project, conducted such a study.¹¹

Netburn developed and tested the relative effectiveness of an audio-tutorial programmed method of teaching the COPES water-mix experiments to fourth graders with the teacher-directed method as recommended in the COPES Teacher's Guides. The study was conducted with fourth grade classes in the Pasadena Elementary School of the Plainview-Old Bethpage Central School District in Plainview, New York. Two of the classes were in the control group. The experimental group used the Audio-Tutorial approach. After preliminary instructions and try out of equipment, these children worked on their own and received directions and thought questions only from the audio-cassettes which had been prepared earlier from the COPES teaching materials and tested in a pilot study by Netburn. Each child worked independently with a cassette-player at a study carrel. Supplies of all necessary equipment were near at hand for him to use as needed. No time limit was imposed upon children for any individual activities. By observing a digital clock each child kept a record of the time he spent with tape and equipment during each self-paced session.

In the two classes making up the control group the same activities were taught by the teacher-directed method by which all children were generally doing the same thing during the same period of time.

Netburn found that children learned as well by the audio-tutorial method as the teacher-directed method. However, the average time required to complete the experiments by the audio-tutorial method was 20 per cent less than by the prescribed teacher-directed method. In these ways it would appear that COPES teaching materials are adaptable to individual instruction as it may be practiced in some classrooms.

¹¹Allan N. Netburn, "A Comparison of the Effectiveness of Two Methods of Presenting Science Experiments to the Children of the Fourth Grade in a Northeastern Suburb." (Unpublished doctoral thesis, New York University, 1971.)

An Investigation Dealing With Children's Concepts of the Relevance of Science

As was brought out in the problems section of this report, some of the science educators associated with the project were concerned about delimiting the COPEs curriculum to "pure" science. Would this result in children failing to get an understanding of or an appreciation for the relevance of science to human beings and their problems? Feerst, another predoctoral fellow in the TTT Project, took this as the problem for her doctoral research.¹² Her study dealt with two methods of presenting a sequence of science activities on heat energy, from the COPEs teaching materials, to 298 fourth grade children in middle class suburban communities in Nassau County, New York. The Science instruction was conducted by the regular classroom teachers, after they had been given inservice training by Feerst. Each of the two groups of 149 children were instructed by one of two methods. The two methods differed in that the experimental method stressed the relevance of the science studied to the children, while the control method did not.

During the experiment, data were collected concerning children's attitudes toward the relevance of science; children's overall achievement on science problems, both computational and verbal; and children's achievement in science as related to application (transfer), learning effect, and retention.

It was found that the experimental method was not effective in improving children's attitudes towards the relevance of science. Furthermore, there was no significant difference between the groups in overall achievement in science. The experimental method was no more effective than the control in improving children's scores on application problems.

From the results of Feerst's study it would appear that the concern of science educators regarding the failure of COPEs to teach the relevance of science, as compared with other ways in which we have attempted to do it, may be unfounded.

An Investigation in Using Selected COPEs Materials with Bilingual Children

Miguel A. Nevarez was in the first class of predoctoral fellows in the TTT Project (1969-1971). He was born in Mexico and was a true bilingual from McAllen, Texas. His primary interest in elementary science was to find effective ways of adapting it to the needs of bilingual children. Therefore, his doctoral

¹²Frances Feerst, "A Comparison of Two Methods of Enriching a Science Curriculum So As to Change the Attitudes of Children Towards the Relevance of Science." (Unpublished doctoral thesis, New York University, 1972.)

research dealt with three methods of oral presentation of a selected sequence of COPES teaching materials to Spanish-speaking children.¹³ He conducted his study in Edinburg, Texas, with six classes of fourth-grade children. He was the teacher by all methods. By one method, only English was used by him and one group of children in working through the COPES water-mix experiments. By the second method, only Spanish was used by him and another group of children in working through the same science activities. By the third method, both English and Spanish were used interchangeably by him and a third group of children in working through the same sequence of activities. The choice as to which language was used by the third method was left up to him and/or the children as it appeared to be necessary in order to communicate clearly. The latter method was the bilingual method of teaching COPES.

Nevarez found that children taught science by the simultaneous use of English and Spanish as the medium of oral communication achieved more than those taught exclusively in English. They also achieved more than those taught exclusively by Spanish. However, children taught exclusively in Spanish achieved more than those taught exclusively in English.

Those of us who worked with Nevarez can now appreciate the manpower it would take to adapt the COPES Curriculum for bilingual teaching. The inservice training of prospective bilingual teachers of COPES represents an additional undertaking of enormous proportions. However, if bilingual children are to be fairly accommodated in COPES, or any other elementary science program, we believe that both must be done.

¹³Miguel A. Nevarez, "A Comparison of Three Methods of Oral Presentation of Science Activities to Fourth Grade Spanish-Speaking Children." (Unpublished doctoral thesis, New York University, 1971.)

CHAPTER VI

THE FUTURE OF COPES

At the time this report is being written the COPES Project has reached a very critical stage in the effort to accomplish its ultimate goal. We have been unsuccessful in obtaining the necessary funds for broad field testing of the teaching materials. We were unsuccessful in our attempts to interest more than one commercial publisher in supporting a modified field test, as a precommitment to that of publishing the COPES materials. (See Request for Proposal (PFD) in Appendix G.) The one publisher was interested in using the COPES teaching materials only where they would fit into an elementary science series that it was preparing for publication. We did not wish to subvert the integrity of COPES by agreeing to such a proposition. Since we have been forced to forego the proposed Field Testing Phase of COPES, as a preliminary to publication, we are now rethinking a variety of propositions to present to publishers that hopefully will be attractive to them and yet not violate the integrity of the COPES curriculum.

If the COPES materials in some educationally defensible forms are not published commercially, the project will have only limited and relatively short-term impact upon the teaching of elementary school science. In the event we are not able to work out a satisfactory arrangement with a publisher, we shall continue to encourage efforts to promote COPES through the resources of the Center for Educational Research and Field Services at New York University. The Center's resources for promotion of such materials are grossly inadequate compared with those of a commercial publisher. The Center will probably not be capable of sustaining the promotion of COPES Teacher's Guides for a longer period than it will take to distribute the preliminary editions in which it has a considerable dollar investment. The cost of the guides has been set merely to recoup this dollar investment. It follows that, under these conditions, the future of COPES is indeed dim.

However, if we are successful in working out publishing and distributing arrangements with a commercial publisher the future of COPES will be much brighter. We would anticipate that over the next ten years COPES, in some clearly recognizable form, would be used in ten per cent of the elementary schools in the country. We further anticipate that the success of the COPES program in elementary schools will be so impressive that it will be extended into the intermediate or middle-school grades. Thus COPES may well become a program of science from Kindergarten through grades eight or nine.

Once domestic publication of COPES has been accomplished the prospects of foreign editions will be good. This prediction is based upon the many favorable responses we have had from foreign delegations who have visited us.

Implications of the research reported in the previous section of this report augur well for the future of COPES. We have evidence that these preliminary editions of the Teacher's Guides include materials that are readily adaptable to college courses in the teaching of elementary school science, at either the undergraduate or inservice level. They may also be used as an orientation base in developing science courses for prospective elementary school teachers. One such experimental course was developed and taught by a chemistry professor at New York University during 1970-1971. His report on the course is included in Appendix G. As will be noted it is enthusiastically favorable.

Because of the manner in which its learning activities are structured COPES should be readily adaptable to the various audio-tutorial technologies that are being produced to meet the demands for self-paced and/or individual instruction in science.

Since COPES is basically pure science it is not contaminated by the cultural orientation of any one ethnic group. It should be readily adaptable to elementary science instruction in different languages.

From a theoretical point of view it would be desirable to extend the studies of the Guilford Structure-of-Intellect Aptitudes, as reported earlier, to other conceptual schemes with which COPES deals. It would then be important for someone to synthesize the findings as a means of determining what aptitudes appear to be important in the science achievement of children as it is defined by one elementary science program.

APPENDIX A

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APPENDIX B

SAMPLES OF MATERIALS FROM THE TENTATIVE TEACHER'S
GUIDE FOR THE STATISTICAL VIEW OF NATURE

Sample of Activities from
Section A

TITLES OF ACTIVITIES IN SECTION A

(Grades K-2)

- Activity A-1: Physical Properties
- Activity A-2: Identifying Objects by Properties
- Activity A-3: Ordering Objects by Properties
- Activity A-4: Interaction Properties
- Activity A-5: Properties of Events
- Activity A-6: Properties of Four Systems (Types)
of Fruit
- Activity A-7: Germination: A Distinguishing
Property of Seeds
- Activity A-8: Cutting Paper Strips to Prescribed
Dimensions
- Activity A-9: Measuring the Circumference of a
Sponge Rubber Ball
- Activity A-10: Variability of Estimates of Length
- Activity A-11: What is the Rate?
- Activity A-12: Pendulum Swings
- Activity A-13: Evaporation Rate of Water
- Activity A-14: Is it Probable?
- Activity A-15: Making Predictions About the Weather
- Activity A-16: Graphing Variation in Size Among
Stones

INTRODUCTION TO ACTIVITIES TO SECTION A

(Grades K-2)

The materials in this section begin with a number of activities designed to acquaint young children with the concept of property as it applies to various objects and events with which they are familiar. They are given a number of experiences in classifying objects into systems based upon properties that are common to them, as well as properties that distinguish one system from other systems. They are introduced to the concept of variability and of nonvariability as it applies to a common property of a system of objects. Variability in making measurements and in estimating measurements is introduced. The concepts of probableness and prediction are emphasized in situations in which children have intuitively used the concepts. Simple graphing techniques are applied in demonstrating variability in sizes of stones in a system.

The sixteen activities in Section A have been arranged in a developmental sequence where each succeeding activity builds upon concepts and skills developed in earlier activities. For this reason, it is recommended that teachers who teach these activities take them up in the sequence in which they appear.

Activity A-5

Properties of Events

In this activity, rather than dealing with properties of objects or materials, we shall consider the properties of events. An event is something that happens, such as a birthday, a rainstorm, a wind, getting up in the morning, going to bed at night, the germination of a seed, the growth of a plant, and the growth of a child. A child's birthday is a big event in his life. The distinguishing property of each child's birthday is the date upon which it falls. Going to bed at night is an event in the daily lives of children. A property of this event is the time at which it occurs. A wind has two properties, the direction from which it blows and the speed at which it blows. Each of these properties may vary during a single day. A rainstorm is usually described in terms of two properties, the amount (inches) of rainfall and the duration (an interval of time). There are two properties of a seed that have to do with the germination event, the viability of a seed (will it germinate?) and the length of time needed for it to germinate.

Materials

No special materials are required.

Preparation for Teaching

From the school records, prepare a list of the birthdays of the children in the class.

Suggestions for Teaching

Age is a property of every living thing, including children. Age is determined by the event of one's birth date. Ask each child in the class to tell how old he is. Write each numeral on the chalkboard. Most of the children will probably be one of two ages since they all are in the same grade. Does this mean that all children who are one age are born in the same month? Does this mean that all children who are the other age were born in the same month?

Write the months of the year on the chalkboard, ask each

child to tell the month he was born, and write his name on the board after the proper month. If some do not know the month, obtain it from the prepared list. Help children to see that they could be divided into groups based upon the month in which they were born.

Property of a System that Distinguishes It
from Another System

Activities A-6 and A-7 continue with the development of the concept of property. They demonstrate further how properties are used in the identification of a system of objects and in distinguishing one system of objects from another. They also show that there may be variability among members of the system in the property that distinguishes it as a system.

Activity A-6

Properties of Four Systems (Types) of Fruit

Materials

- 2 oranges with seeds
- 2 lemons with seeds
- 8 apples of assorted sizes and colors
- 1 knife
- 1 lime with seeds
- 1 grapefruit with seeds

Preparation for Teaching

In selecting the oranges and lemons, try to have each member of the pair slightly different in size, color, or shape. Place all fruit except the lime and grapefruit on a table in an unorganized collection.

Suggestions for Teaching

Call the children's attention to the collection of objects on the table. Ask them to name the objects. If the objects are named individually, ask what the entire collection is called. Write the word fruit on the chalkboard. Invite one of the children to arrange the fruit in three groups. Have another child name each group. Write the word orange on the board under fruit. Hold up the two oranges and ask how they are different. Then ask

why we call them oranges. Encourage children to identify such properties as pebbled skin texture, round shape, and smell or taste as properties that distinguish oranges from other fruit. Go through the same procedure with the lemons and apples.

Tell the class that you are going to cut each fruit to find out if there are other ways in which fruits are alike. Cut in half one of each kind of fruit. Cut horizontally rather than vertically through the stem end of the fruit. Show the class that each fruit contains seeds. Tell them that this is why the scientist calls each a fruit. Identify the characteristic cross-sectional appearance of each kind of fruit. Cut two of each kind of fruit to show that the cross-sectional appearance of each kind is the same. Call attention to the wedge-shaped sections of the oranges and lemons and to the five-pointed, star-shaped center in the apples.

Now invite six children to cut the remaining apples. Before each cuts his apple, ask him what he predicts the center will be like. As each apple is cut, have the centers shown to the other members of the class. Although the apples were different in size and color, each has the five-pointed, star-shaped center. (From the point of view of the botanist, this is one of the unique characteristics of the group of plants to which the apple trees belong.) Regardless of the size, shape, color or texture of the skin of an apple, the five-pointed, star-shaped center is a property that is common to all apples. Impress children with this point.

If you think of apples as a system with the five-pointed, star-shaped center as a common property distinguishing its members

from the members of other systems of fruit, then you could predict that all members of the apple system would have this property. However, it is probable that on some future occasion you might find an apple with the other properties of apples, but which has a four or six-pointed star-shaped center. This may happen as a result of an "accident" in the formation of the flower from which the apple developed or an "accident" in the formation of the apple.

Show the lime and the grapefruit. Ask which of the three other fruits (lemon, orange, or apple) they are most like. It will be noted that the skin and citrus aroma is similar to that of the lemon and orange. Ask what else could be done to establish the relationship of the lime and grapefruit to the orange and lemon. Have them recall the appearance of the orange and lemon when they were cut in half. Would they expect the lime and grapefruit to have the same wedge-shaped sections? Now cut them and observe that they do. Although oranges, lemons, limes, and grapefruits have some distinctly different properties (color, shape and taste) they all have the common property of wedge-shaped sections. This identifies them as belonging to a larger system, citrus fruits. Each type of citrus fruit is a sub-system of the larger system. With reasonable assurance, you could predict that all citrus fruit would have this one property.

Sample of Activities from
Section B

INTRODUCTION TO ACTIVITIES IN SECTION B

(Grades 3-4)

The activities included in Section B build in a progressive manner upon the concepts and skills developed by those in Section A. Variation and variability are revisited at a more sophisticated level than in Section A. This is done in both physical and biological systems. The concept of range of values and middle value (mean) are introduced and applied to the analysis of variability in several systems. Histograms and frequency distributions are used in arriving at overall descriptions of variability and in making predictions. The concepts of sample and sampling are also developed. The relationship of sample size to confidence of prediction is demonstrated. One activity dealing with chances is introduced as the precursor to the concept of probability.

The seventeen activities in Section B have been arranged in a developmental sequence where each succeeding activity builds upon concepts and skills developed in earlier activities. For this reason, it is recommended that teachers who teach these activities take them up in the sequence in which they appear.

ACTIVITIES IN SECTION B

(Grades 3-4)

- Activity B-1: Temperature (F°) of Water Systems
- Activity B-2: Temperature (F°) of Air Systems
- Activity B-3: Heat Transfer by Contact
- Activity B-4: Variability of Out-of-Door Air Temperature from One Place to Another
- Activity B-5: Out-of-Door Air Temperature from Hour to Hour in One Place
- Activity B-6: Variation in Rate of Dissolving
- Activity B-7: Variability in Germination Period of Seeds
- Activity B-8: Finding the Average Number of Roasted Peanuts in Bags
- Activity B-9: Finding the Average Length of Roll of a Marble
- Activity B-10: Finding and Checking Average Temperatures
- Activity B-11: Setting Up a Frequency Distribution of Heights and Making Predictions from the Distribution
- Activity B-12: Setting up a Frequency Distribution of Lengths of Middle Fingers and Making Predictions from It
- Activity B-13: Setting up a Frequency Distribution of Midrib Lengths of Escarole Leaves and Using the Distributions to Make Predictions
- Activity B-14: One out of Two Chances
- Activity B-15: One out of Three Chances
- Activity B-16: Chances of the Occurrence of Events
- Activity B-17: Studying Samples of Wind Direction

Activity B-5

Out-of-Door Air Temperature from Hour to Hour in One Place

From 9 A.M. to 2 P.M., have children check the air temperature every hour in one location on the school grounds. Make certain that all air temperatures are taken in the shade. If temperatures are taken in the sun you will not be measuring air temperatures but the heating effect of the sun's rays on the thermometer.

Keep a record of the hourly temperatures on the chalkboard. Prepare a bar graph of the temperatures. Calculate the range of temperatures over the five-hour period. Use the leveling technique to find the temperature that is most representative of all five temperatures.

Discuss ways in which the graph might be used to predict tomorrow's air temperatures during the same period. What range of temperature would you predict? Would you expect the range to be much different from what it was today? What representative temperature would you predict? Would you expect it to be much different from today's.

Have children keep a record of air temperatures for the same five-hour period for each of ten days. The days do not necessarily have to be consecutive. Graph each day's record in the same manner that was done for the first day. Compare the graphs. Are the minimum temperatures and the maximum temperatures the same each day? If not, how much does each set of temperatures vary? How much does the representative temperature vary?

Prepare separate graphs of : (1) the minimum temperatures,

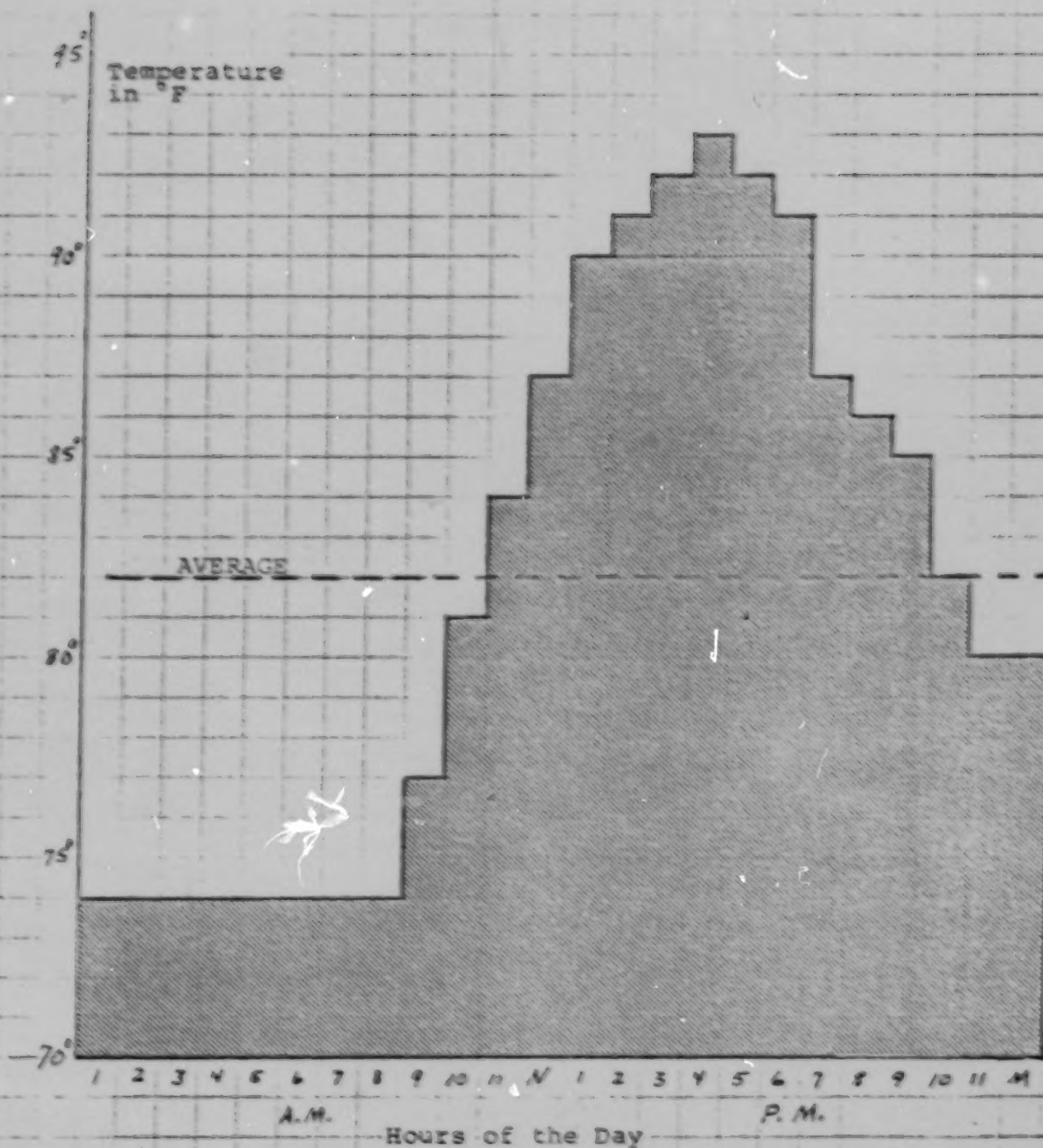


Figure B-5
Hourly Temperature Records
New York City, July 23, 1968

(2) the maximum temperatures, and (3) the representative temperatures for the ten-day period. By using the leveling technique, calculate the representative temperature of each of the three. If you had used these representative temperatures in predicting each of the three temperatures each day, would your predictions have been closer than using one day's readings as a basis for predicting the next day's?

Have children obtain the hourly record of temperatures for ten consecutive days from a local daily newspaper. (For schools in communities where the newspapers do not publish such records, records for other cities could be supplied as "canned data".) For illustrative purposes, the following is a 24-hour record of temperatures in New York City for July 23, 1968.

1 AM: 74°F	7 AM: 74°	1 PM: 90°	7 PM: 87°
2 AM: 74°	8 AM: 74°	2 PM: 91°	8 PM: 86°
3 AM: 74°	9 AM: 77°	3 PM: 92°	9 PM: 85°
4 AM: 74°	10 AM: 81°	4 PM: 93°	10 PM: 82°
5 AM: 74°	11 AM: 84°	5 PM: 92°	11 PM: 80°
6 AM: 74°	Noon 87°	6 PM: 91°	Midnight: 80°

Give each of ten children one day's records and have them graph the temperatures as they did for the five-hour period. (Figure B-5 is a graph of the above temperature data for July 23, 1968.) After the maximum temperature, minimum temperature, range of temperatures, and representative temperature of each day have been determined, use these as bases for predicting what the next day's temperatures will be as was done previously for the five-hour periods. Then graph maximums, minimums and representative temperatures for the ten-day period, and use these as bases for predicting each day's temperature. Which turned out to be the better basis for prediction?

Sample of Activities from
Section C

INTRODUCTION TO ACTIVITIES IN SECTION C

(Grades 5-6)

It is in Section C that many of the concepts having to do with the statistical view of nature come to fruition. Variability is investigated in broader contexts than in earlier activities. The relationship of sample size to confidence of prediction is again demonstrated. The concept of random behavior is introduced for the first time and demonstrated in a variety of natural events. The concept of theoretical probability is developed and applied to relevant situations in earlier experiences. The relationship of large numbers to probability is investigated. Several activities of a nonquantitative nature are included to demonstrate how natural, disordered events may, under certain conditions, become ordered. Finally, many of the previously developed concepts are applied in an explanation of the inheritance of eye color in houseflies. Other activities open the door for a future look at the kinetic theory of gases, entropy, and radioactive disintegration from a statistical view.

The thirty-four activities in Section C have been arranged in a developmental sequence where each succeeding activity builds upon concepts and skills developed in earlier activities. For this reason, it is recommended that teachers who teach these activities take them up in the sequence in which they appear.

ACTIVITIES IN SECTION C

(Grades 5-6)

- Activity C-1: Variability in Earth's Atmosphere:
a Natural System
- Activity C-2: Seed Germination
- Activity C-3: Predicting Lengths of String Beans
- Activity C-4: The Unpredictability of Random
Behavior
- Activity C-5: The Fall of Flat-sided Seeds
- Activity C-6: Wind-blown Seeds
- Activity C-7: Layering of Sand and Soil Particles
- Activity C-8: The Shape of Crystals
- Activity C-9: The Crystal Model
- Activity C-10: Slow and Rapid Cooling
- Activity C-11: Sulfur Crystals
- Activity C-12: The Camphor "Walk"
- Activity C-13: Plotting a Random Walk
- Activity C-14: Bringing Order Out of Randomness
- Activity C-15: A Trip by Chance
- Activity C-16: A Probability Distribution
- Activity C-17: A Probability Demonstration
- Activity C-18: A Distribution Curve in Nature
- Activity C-19: Chance Events
- Activity C-20: Predicting Results of a Single
Independent Event
- Activity C-21: Chance and Probability
- Activity C-22: Probability and Number of Possible
Outcomes

- Activity C-23: Independent and Non-Independent Events
- Activity C-24: Accuracy of Prediction and Number of Events
- Activity C-25: Unequal Chances
- Activity C-26: Inferring the Composition of a Many-Membered System
- Activity C-27: Probability of Various Combinations of Events
- Activity C-28: A Model for Explaining Inheritance of Eye Color in Houseflies
- Activity C-29: Dissolving Salts
- Activity C-30: Diffusion of a Solution in a Liquid System
- Activity C-31: Diffusion of a Gas
- Activity C-32: A Model of Diffusion
- Activity C-33: Disorder from Order: Is it Reversible?
- Activity C-34: Radioactive Disintegration as a Chance Event

Activity C-31

Chance and Probability

This Activity is intended to review the idea that the probability that a given result will occur depends upon how many different results are possible.

Materials

- 1 container, opaque
- 5 beans, dried, white
- 5 felt-tipped pens (one each of the following colors:
black, red, blue, orange, yellow)

Preparation for Teaching

Use a felt-tipped pen to color a large dot on both sides of each bean. A different color should be used for each bean. Allow the ink to dry for an hour or more so that the colors will not smear when the beans are handled.

Suggestions for Teaching

Show the children one bean of each color, and then put all five beans into the container and shake them. Ask the children how many different results (colors) are possible if the beans are drawn from the container. Undoubtedly, they will recognize that only five different results are possible. Then ask what are the chances that the first bean drawn will be red. Help the children understand that, since only one color is to be drawn from the five possible colors, the chances are 1 out of 5. Now would be a good time to use the term probability by saying that the probability of drawing a red bean is 1 out of 5, or $1/5$. Ask the children to convert the common fraction $1/5$ to a decimal fraction, and tell them that the probability (p) of drawing a red bean is usually expressed as $p = 0.20$ and that this value means 2 chances out of 10, or 1 out of 5. Write the probabilities on the chalkboard as follows, and call children's attention to the fact that the sum of all the probabilities is 1.0.

red, p =	.20
blue, p =	.20
orange, p =	.20
black, p =	.20
yellow, p =	.20
sum, p =	1.00

Tell the children that you will ask each of them to draw a bean, note its color, and return it to the container. When 30 beans have thus been drawn, how many of them can be expected to be red? orange? blue? black? yellow? In each case, the expected result is 6 since in each of the 30 draws the chance of drawing a particular color was 1 out of 5, or 0.20 ($30 \times .20$). As the children draw the beans in the manner described, record the results as shown in the tally column of the table shown in Figure C-21.

Color	Tally	Total Times Drawn	Out of	Portion of Cases Drawn
red		4	30	.13
blue		6	30	.20
green		7	30	.23
black		8	30	.27
yellow		5	30	.17
Average				.20

Figure C-21

Fill in the next two columns of the table in the manner shown. Then have the children express the portion of the cases that each color was drawn by converting the common fraction to a decimal fraction, for example $4/30$ to 0.13. When they have done this for each color, ask them to compare the results with the probability determined on the basis of logical considerations. They are likely

to find that some results were greater than 0.20, while some were less than 0.20. Possibly, no result was exactly 0.20. (Much of the discrepancy between results and probability is due to the effect of a relatively small number of drawings.) Ask the children what portion of the cases, on the average, was each color drawn. Have them find the average of the decimal fractions in the last column, which will always be 0.20, except possibly for small discrepancies due to rounding off. Emphasize the fact that although the results for each color were not always the same as the probability, the average result for all colors was the same as the probability for drawing any one of the colors.

APPENDIX C

EXCERPT FROM A COPES LABORATORY SCHOOL REPORT

COPES Laboratory School Report

Activity: C-21 Chance and Probability
and

C-22 Probability and Number of Possible Outcomes

I began the session by showing the children one bean of each color,
and then put the five beans into the containers and shook them.

Question: "How many different results (colors) are possible
if the beans are drawn from the container?"

Response: "Five."

Question: "What are the chances that the first bean drawn will
be black?"

Response: "One out of five"

"It's the same as one-fifth"

Question: "What is the probability that a red bean will be
drawn?"

Response: "One out of five"

Question: "How would we state this in terms of a decimal?
Anyone have any idea?"

Response: "What's a decimal?" (4th Grader)

"It's ah, it can mean - it's hard to explain. A ten-
it can be - oh, I can't explain it (4th grader)

"It's the separation between a whole number and
fractions of that whole number - like tens and
hundreds and thousands and hundred thousands, and
so on."

"And the answer is .20 "

Question: "How many people have worked with decimals?"

1 - 4th grader

1 - 5th grader

2 - 6th graders

Question: "How would we state this in terms of a decimal if we were talking about one-fifth?"

Response: ".10"

"twenty hundredths"

Question: "What is the probability of drawing any one of the five colors? How would we express this as a decimal?"

Response: "twenty hundredths"

Question: "How would I write twenty hundredths?"

Response: "I don't know, but maybe 28?"

"1/5"

"Well, first you make the point, the part that's the decimal, and on the left side of it, zero would be - no, the point would be the middle. On the right side would be tenths, hundred, thousands, ten thousands. The whole numbers would be on the left."

Question: "Is 2/10 and 20/100 written the same way?"

Response: "No"

".02"

"That's two hundredths"

"No it isn't because -"

"You would read it two tenths."

"It doesn't matter."

Question: "Mark, how did you get your answer?" (.20)

Response: "Well, I think she said that it was .02 and zero is in the tenths column and 2 is in the hundredths column, so that would be two one hundredths."

"Mark is right, it should be .20."

Question: "Fine, if the 2 represents tenths and the zero represents hundredths, how many fifths would I have if I picked out one bean?"

Response: "One-fifth and you can change that to two-tenths."

Question: "How would I change the fraction $1/5$?"

Response: "Well you multiply it by the same number. Like if you want to get $2/10$ you multiply $1/5$ by two."
(6th)

Question: "What is this $1/5$ of?"

Response: " $1/5$ of $2/10$ is simplifying it." (4th)

Question: "How did Mark get his answer of 0.20?"

Response: "Because of $1/5$ of 100."

"It's equivalents."

Question: "If I take $1/5$ of 100, I can divide the 5 into 100 and I get?"

Response: "Twenty"

Question: "How do I get the decimal point there?"

Response: "Because you have no wholes. $1/5$ is not a whole."

"It is twenty one-hundredths and it is the same thing as $1/5$."

Question: "What is the probability of drawing any one of the five beans if I express it in decimals?"

Response: "Twenty hundredths"

"Two tenths"

Question: (on board) "Can anyone give me the probability for the red bean? ".20"

" " green bean ".20"

" " blue " ".20"

" " yellow " ".20"

" " black " ".20"

Response: "They all have an even chance."

APPENDIX D

EXHIBITS FROM THE TEACHER'S GUIDES FOR K-2

Selected Activities from the Kindergarten
Part of the Teacher's Guide for K-1

TOPIC 1: IDENTIFYING THINGS AROUND US

Activity 1: Some Things Around Us

TEACHING OBJECTIVES

Skills	Phenomena	Concept Goals
Observing	things around us	to emphasize the importance of observational awareness
Communicating	by making records or pictures	to build a collection of objects with different properties

Key Vocabulary: None

Materials:

drawing paper, one sheet for each child
crayons

Preparation for Teaching: No special preparation is needed.

INSTRUCTIONAL SEQUENCE

1. Identifying Things in Our Environment

Tell the children that you would like to have them play a game with you.

Ask them to take some time to observe carefully all of the different things in their classroom.

After one or two minutes ask them to close their eyes.

Invite different children to recall one of the things they saw.

As each child names something, write it on the chalkboard.

COMMENTARY ON THE SEQUENCE

The first part of this activity may be completed in one class session. Its purposes are to encourage careful observation and to develop the idea that there are many different things in our surroundings. The whole activity may be completed in 2-3 sessions.

If you can think of other appropriate ways of introducing this activity you should feel free to do it your way.

You may want to tell the children that you are writing the names on the chalkboard so you will remember them later. Although your children

INSTRUCTIONAL SEQUENCE

After the children can no longer recall items, have them open their eyes, observe the classroom again, and name the things that may have been omitted from the first list.

2. Many Different Things in Our Environment

Ask the children to think about the different things they saw on their way to school.

Invite a number of children to name one or more things.

Encourage each child to make a drawing of one of the things he saw.

Have each child show his drawing to the class, tell about it, and identify it by name.

Write the name of the object shown in each drawing on the paper.

Have the children arrange their drawings on the bulletin board or another suitable place where everyone can see them.

As the children observe the display, call attention to how many different things are shown. Were all of the things named earlier shown in the pictures? Which ones were not?

COMMENTARY ON THE SEQUENCE

may not be able to read the list of names, it can be used later to demonstrate the relatively large number of different things in the classroom. It can also be used for the grouping experiences in Activity 2.

When items are named the second time, use the list to indicate to the children whether, according to your record, it is an item that was not named earlier.

The next part of this activity may take as many as two class sessions: one to name the things, the other to draw the things. Its purposes are to emphasize careful observation and to impress the children with the idea that there are many different things in our surroundings.

To help children concentrate on recalling what they saw, you might encourage them to close their eyes.

If a child says that he recalls something but is unable to name it, encourage him to describe it. From his description others may help him name it.

Another way by which children can keep a record of what they saw would be to cut out suitable pictures from old magazines. The cut-outs could then be pasted on drawing paper.

If the school has a Polaroid camera it might be used in taking photographs of some of the things the youngsters saw.

In discussing these questions, help the children to acknowledge the idea that there are many different things around us, both in the classroom and outside the classroom, and that we can record our observations of these things.

TOPIC 1: IDENTIFYING THINGS AROUND US

Activity 1A: Creating an Environment for Living Things (optional)

TEACHING OBJECTIVES

Skills	Phenomena	Concept Goals
Observing	living things around us and what they and how they change	need to survive in their environment as a result of interaction with the environment
Communicating	by beginning to record observations	so that they may be compared later as evidence of changes
Interpreting	observations of properties of things	as evidence of interaction of living and non-living things in the environment

Key Vocabulary: change, living, environment

Materials: Please refer to the Appendix of this guide for instructions on how to establish and maintain an aquarium and a terrarium, and how to care for living organisms in the classroom.

Preparation for Teaching: See Appendix for instructions

INSTRUCTIONAL SEQUENCE

COMMENTARY ON THE SEQUENCE

The purpose of these activities is to help children set up different environments for direct observation of living organisms. These environments can be used on a continuing basis throughout the school year to help achieve a variety of teaching objectives and to exemplify various concepts developed as a part of the science program.

Activities involving living organisms may be initiated in many different ways. Use your own judgment in planning for timely and appropriate entries to these learning experiences.

1. Preparing Special Environments

Provide opportunities for the children to help plan the set up of one or more environments.

INSTRUCTIONAL SEQUENCE

Discuss some of the general needs of organisms, such as food, air, moisture, light, and any other factors which might influence survival and normal growth.

Encourage children to participate in collecting materials which will become part of the environments.

Set up the environments with the class.

Review with children some of the different things in the environments, as you did in Activity 1.

2. Observing the Environment

Work with children to develop a program of regular care and observation of the environments.

Discuss properties of the objects in the environments, with reference to particular attributes such as size, color, shape, texture, and solid or liquid.

Discuss and amplify the inter-relationship of parts to the whole.

COMMENTARY ON THE SEQUENCE

Children need not be specific in describing the needs of each organism, but they should be helped to develop a broad understanding of the general needs of living organisms.

Materials suitable for a terrarium can usually be obtained by the children. If an aquarium is to be established it may be possible to obtain some supplies or materials from a parent in the community or from another teacher who is maintaining aquaria at home or in a classroom.

See the Appendix containing specific instructions for establishing and maintaining various environments.

Children's interests will be high for several weeks. You can expect, however, that their major attentions will subsequently be directed to following portions of the program.

A few days after you and the children set up plans for care and observation of various environments, you should move ahead in the program to subsequent activities. Then, from time to time later in the program, there will be opportunities to direct attention again to the environments and to exemplify or reinforce science concepts as suggested below.

These discussions may accompany class work in TOPIC 11. Where possible, children should be encouraged to interact with organisms. Provide and discuss adequate safeguards concerning the health and well being of children and other living organisms in the environments.

INSTRUCTIONAL SEQUENCE

Compare sizes and amounts of living and non-living objects in the established environments.

Discuss the observed properties of the objects.

Ask some children to make or keep simple records of their observations. Discuss their records with the class.

Continue to discuss changes in the living organisms and/or the environments.

COMMENTARY ON THE SEQUENCE

In connection with TOPIC III many opportunities will arise for making comparisons. Plants grow taller, the number of leaves increases, colors change, fish or other animals may reproduce or die, water in an aquarium will evaporate, and many other changes will be observed taking place in the environment.

You will no doubt anticipate some of these changes and plan your discussions accordingly. With the passage of time children will gradually become aware of changes in properties, sizes and quantity, and should be helped to recognize and verbalize these changes.

Records can be made in various ways as suggested in TOPIC III. Help the recorders to set up a meaningful display so that the class can refer to the record periodically and discuss their findings.

In TOPIC IV emphasis is placed on changes. Use your discretion to relate the activities in TOPIC IV to the changes in the environmental systems that have been observed.

TOPIC I: IDENTIFYING THINGS AROUND US

Activity 2: Arranging Objects into Groups

TEACHING OBJECTIVES

<i>Skills</i>	<i>Phenomena</i>	<i>Concept Goals</i>
Observing	various objects	to evolve properties that reflect their differences and similarities
Classifying	objects into groups	as a result of describing them by their properties
Communicating	by telling and recording what properties	are useful in describing and classifying objects

Key Vocabulary: to group, a group

Materials: Various relatively small, portable objects to be found in a classroom and in a selected outdoor environment, several paper plates

Preparation for Teaching: No special preparation is needed

INSTRUCTIONAL SEQUENCE

Ask someone to review what was done in the games they played in Activity 1.

Tell the class that they are going to play another kind of game with some of the same things.

1. Grouping Objects

Ask each of ten children to select some object from the classroom and place it on a centrally located table.

Now ask for a volunteer to pick two or more items that are alike in some way, or belong together. Tell the children that these things form a group. A group is a collection of things that are like each other in some way. Ask the volunteer to tell how his items are like each other.

After he has completed the task, ask him to tell about the groups into which he has arranged the objects.

COMMENTARY ON THE SEQUENCE

We have suggested only one way of introducing this activity. You may think of other ways for your pupils.

Don't discourage the children from selecting similar items. A few of the same type of item may be helpful in getting the grouping activity started. The ten objects may contain only one obvious subgroup. Should this occur, either get more objects so that two or more groups are clearly possible or, as an alternative, ask one child to make one group and tell about it; then ask another child to make another group, using some of the objects from the first group if needed, and tell about it, and so on.

Allow the child to arrange the objects in whatever groups he may choose.

This question is asked to encourage children to think about the properties of the objects that were used in arranging them into groups. Objects in the same group all share some common property. Objects in different groups have one or more different properties. For example, certain objects might be put into one group because they are soft and into another group because they are hard. Or they might be grouped according to function. Some may be objects that can be used to write with, whereas others may be objects that you put things into.

INSTRUCTIONAL SEQUENCE

Mix the objects. Ask for another volunteer to arrange them into two or more different groups and to tell about the new groups.

If interest has been sustained, ten more objects selected from the room might be substituted for those on the table and other children invited to arrange them into groups.

2. Kinds of Groups

If possible, take the children for a walk in the school yard, a nearby woods, or a vacant lot. Encourage them to pick up small objects that they may find along the way and to take the objects back to the classroom. Put the objects on a table.

Place a row of 4 or 5 paper plates along one side of the table.

Suggest that various children, individually or in small groups, arrange the objects into two or more groups by placing objects that are alike in some way on a plate, each group on a different plate. Encourage them to tell about the groups they have formed.

Suggest that each child investigate ways in which his mother groups the many different objects in her kitchen at home. At the next class session, discuss the findings.

COMMENTARY ON THE SEQUENCE

You may want to repeat this as many times as children find new ways of grouping the objects.

After each new grouping, encourage the children to tell about the groups into which they arranged the objects. How are the objects in one group alike? How are objects in separate groups different? Return from time to time to a discussion of what the term group means: a collection of things that are like each other in some way.

Whereas a number of the objects found in the classroom will probably be man-made ones (pencils, erasers, chalk, ruler, cups, containers, etc.) many of those found outdoors will be natural objects (rocks, leaves, insects, worms, weeds, flowers, twigs, etc.). This may affect the kinds of groups into which the objects are placed.

Once it appears to you that the children understand what is involved in forming different kinds of groups, discontinue the lesson. However, leave the materials on the table and encourage the children to try different arrangements when they have free time.

You may want to use the following questions to discuss the findings:

1. How are the knives, forks and spoons grouped?
2. How are spoons alike? How are some spoons different from other spoons?
3. How are forks different from spoons?
4. How are knives different from forks? How are some knives different from other knives?

Questioning such as the above can be used in discussing cups, saucers, plates, pots, pans, bottles, cans, flour, sugar, salt, and other such items found in the kitchen.

Selected Activities from the Grade 1
Part of the Teacher's Guide for K-1

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TOPIC 11: MEASUREMENTS

Activity 1: Ordering Objects in Terms of Size

TEACHING OBJECTIVES

Skills	Phenomena	Concept Goals
Observing	groups of different sized objects	to reinforce the property of dimensions, such as length, area, volume
Measuring	the rise in water level as different sized objects are placed in it	
Interpreting	the above measurements	to associate the amount of displaced water with the size of the immersed object
Measuring (by estimating)	the comparative dimensions of one property of a group of objects	to reinforce the concepts of longer than, shorter than; more than, less than, etc.
Classifying (by ordering)	similar objects within groups	to reinforce the concept of serial ordering with respect to a dimensional property such as -- shortest to longest, or least to most

Key Vocabulary: longer-shorter, taller-wider, longest-shortest, more than-less than, most, greatest, least, amount

Materials:

- 6 straws, each cut a different length, same color if possible
 - 6 cubes, same color, each a different size, one must be 1 cubic inch
 - 1 marking pencil or crayon
 - 6 spheres (balls, beads, marbles), each a different size
 - 1 pkg. plastic clay
 - 1 bottle of food coloring or powdered dye
 - 1 jar, transparent, similar to a slender olive jar, mouth of bottle should allow a one-inch cube to be dropped into it, or use a pint or quart jar
 - 1 pitcher, or large jar
 - 1 spool of thread
 - 3 cups of sand
- The following materials for each child or group of children:
- 6 strips of paper, each strip 1" wide but each a different length -- 8", 7", 6", 5", 4", 3"

6 squares of paper, 1", 1 1/2", 2", 2 1/2", 3", and 3 1/2"
12 transparent containers, same size, such as baby food jars or glasses

This activity may be completed in 6 or 7 class sessions. It is intended as an extension of concepts introduced in TOPIC III, Activity 1 of the Kindergarten Sequence. If the children have not had previous experience in comparing the dimensions of two similar objects, you will probably want to refer to that activity before proceeding with this one.

The purpose of this activity is to extend the concepts introduced in Kindergarten and to continue to build a vocabulary of comparative terms useful in describing relative sizes. Children will be comparing more than two similar objects and will be introduced to ordering groups of objects on the basis of lengths, areas, and volumes or amounts.

Preparation for Teaching: Because of the length of this activity, it has been divided into seven parts (A-G). The preparation for teaching each part is presented at the beginning of that part.

Part A: Ordering Objects Based Upon Length

Obtain six straws, preferably the same color, and cut them so that each is a different length.

INSTRUCTIONAL SEQUENCE

Place two straws side by side on a horizontal surface.

Ask the children to relate how the two objects (straws) are alike.

Now ask the children to tell you how the two objects are different. Ask them to use words that tell (describe) the difference.

Clarify that children are speaking of the length of the object from one end to the other.

Ask one child to use his hands (or fingers) to show how the straws are different in length. Encourage use of the terms longer than and shorter than in length.

Once again, place two straws side by side on a horizontal surface. Add another even longer straw to

COMMENTARY ON THE SEQUENCE

Line up the straws so that the class can readily observe their difference in length.

Children should remark that the colors, the shapes, and other features are alike. They may also indicate similarity of functions and name the objects.

Children should state that one of the straws is longer than the other, or that one is shorter than another. Each description is acceptable.

When determining longer than or shorter than, be sure the terms are referring to the length of the straw. Children will probably use the length of one straw to determine the relative length of the other. For example, some may select the longer straw and interpret the other straw as being shorter. Other children may view the straws in the reverse manner and call one shorter than the other.

Establish with the children that the new straw is the longest (in length) of the three when

INSTRUCTIONAL SEQUENCE

the display, placing the new straw so that the three straws are ordered from shortest to longest.

Ask one child to point out which straw in the group is the shortest in length. Put these straws aside.

Using the remaining three straws, repeat the procedure just described.

Next, arrange the six straws so that the relative lengths are not apparent. Ask a child to choose three straws. Tell him to place them on a table or a floor and arrange them in order from longest to shortest. Be certain that the ends of the straws line up with each other. Now ask the children to describe their lengths.

Replace the straws in a bundle. Using the same procedure, invite other children to choose three, then four, then five straws at a time and arrange them on the basis of length. Finally, ask one child to order the entire bundle of straws, using the proper terms in describing their lengths.

Part B: Ordering Objects Based Upon Length and Area

Prepare the following materials for each child or group of children:

6 strips of paper (see materials list for dimensions), all the same color.

COMMENTARY ON THE SEQUENCE

referring to the relative lengths of members of the group.

Establish that this straw is the shortest of the three, when referring to the relative lengths of members of this group.

Children will probably identify the longest and shortest straws (in length) first. Then beginning at one side of the group of straws, they will compare each successive straw with the one next to it. For example, if they started at the side where the shortest straw is located, the second straw lying next to the shortest will be longer than the shortest. The third one will be longer than the second, and so on until they come to the longest of all.

Arranging straws in order is one way of determining which is the shortest and which is the longest straw. Some children may suggest that you place the straws in a bundle and tap one end of the bundle against a table top as a way of locating the longest and the shortest.

Throughout this part, emphasize that the comparative terms longest and shortest, longer and shorter are being used with reference to length.

INSTRUCTIONAL SEQUENCE

6 squares of paper (see materials list for dimensions), all the same color.

Furnish each child or group of children with six paper strips of different lengths as described in the materials list at the beginning of the activity. Ask them to arrange the strips from longest to shortest in length.

Furnish each child or group of

COMMENTARY ON THE SEQUENCE

As indicated by its title, this part of the activity consists of two experiences. One part deals with the length of objects. In ordering the strips, children are encouraged to describe them in terms of longest and shortest.

The second experience gives the children an opportunity to work with squares of paper. They describe them in terms of ordering and in terms of largest and smallest. Although area rather than length is the basis of comparison, the intent of the second part is to assess the children's ability to order on the basis of area covered. Therefore, you may wish to complete this activity in one session, using the second part to evaluate the effectiveness of the learnings which have been developed.

It may be helpful to show the children that the edge of the desk nearest to them may be used as the "starting point" for each strip. That is, the ends of the strips may be placed even with the edge of the desk. However, if some children wish to place the strips in a horizontal position, they should be encouraged to do so.

Continue to emphasize that when we describe longest and shortest in this ordering process, we are referring to length. As mentioned in the Kindergarten Sequence, these same terms may be used to compare periods of time. For this reason, you may want to emphasize that these terms are being used in relation to a linear dimension (length) and not to time.

Children should be encouraged to describe the ordering of the strips in terms of longest and shortest. As with the straws, intermediate comparisons may be made in terms of longer and shorter.

The emphasis here should be based

INSTRUCTIONAL SEQUENCE

children with six squares of paper. Ask them to order the squares on the basis of the amount of space they cover.

COMMENTARY ON THE SEQUENCE

on the concept that one square is larger than or smaller than other squares because of the space (area) it takes up when placed on a flat surface.

The square covering the most space is the largest, and the one covering the least space is the smallest.

You may wish to use other sheets of paper to assess the children's ability to compare objects on the basis of area.

Part C: Ordering Cubes Based upon Volume

Assemble approximately 6 cubes (see materials list) and a marking pencil. If possible, they should all be the same color. Prepare a 1 cubic inch plastic clay model and attach a piece of thread to it. Fill an olive jar half full of water.

Place two cubes on the table, one distinctly larger than the other. The smaller of the two should be 1 cubic inch, if possible. Ask the children how the cubes are alike.

Now ask the children how the two cubes are different. Once the property of size is mentioned, discuss with the children the meaning of size as used in reference to the cube (length, width, height).

Have the children look at the cubes once again. Which one is taller than the other? Which one is longer than the other? Which one is wider than the other?

The similar properties are shape, equal length edges, and possibly color.

The difference in size should be mentioned.

In the case of the cube we need to refer to the three dimensions, length, width and height or to the total space it occupies. (We call this its *volume*.)

You will want to take time to be certain that the children understand that taller than refers to the distance measured from the base of the object to the top of the object as it rests on the desk. Height is distance in a vertical direction. The length of a cube refers to how long the object is in one horizontal direction, and the width refers to the other horizontal direction. With blocks that are not cubes, the length of the block will be its longest horizontal dimension and its width will be its shorter horizontal dimension.

INSTRUCTIONAL SEQUENCE

Help the children understand that when we refer to the size of a cube, we are really thinking about and comparing the total amount of space taken up by the cube. To illustrate this, fill an olive jar half way with water. Have a child place a mark on the jar at the uppermost level on the water in the jar. Make a model of the small cube from plastic clay, tie it securely with a piece of thread, and ask a child to submerge the cube into the water in the jar. Ask another child to make another mark at the uppermost level of the water when the cube is submerged. Remove the cube and discuss the results. Ask such questions as: "Did the level of the water rise when we placed the cube into the jar of water?"; "What causes the level of water to rise?"; "Did the level of the water go down again when we removed the cube?" "What do you think might have caused this to happen?"

Then ask what they think would happen if we were able to fit the larger cube into the jar. Would the water in the jar remain the same or would it move up higher than when the smaller cube was placed in the jar?

Now, display the remaining cubes. Ask for a volunteer to place them in order on the table from the largest to the smallest.

Part D: Ordering Spheres Based upon Volume

Assemble approximately 6 spheres (see materials list). It is doubtful if you will be able to obtain spheres of the same color or type for this part of the activity. Prepare a plastic clay model the same size as one of the smaller spheres (small enough to fit into the mouth of the olive jar).

COMMENTARY ON THE SEQUENCE

If an olive jar is not available, you may substitute a pint or quart jar, but the displacement of the water in the pint or quart jar will not be as noticeable, therefore the slender, taller, cylindrical jar is recommended.

The fact that the cube takes up a definite space or volume can be illustrated by using the method suggested.

Encourage the children to tell what they think might have caused the water to rise. The emphasis here is that the cube takes up or fills a certain space. We call that space its volume. When the cube is put into a bottle of water, the water must rise in the bottle because the cube takes up a certain space. The more space it takes up (the greater its volume) the higher the water will rise.

Tell the children that they will have an opportunity to test out their ideas with materials that you will place in a work area for them. Encourage them to test other materials which they find in the room or bring in from home. Larger-mouthed bottles may have to be used with larger cubes. However, comparisons of volume should always be made with a bottle or jar of the same size for each cube and with the same amount of water in it.

The concept of ordering in terms of relative size is reintroduced at this time.

INSTRUCTIONAL SEQUENCE

Attach it securely with thread. Fill the olive jar half full of water. A marking pencil will be needed.

Repeat the procedure as in Part C, using spheres of different sizes.

Begin with a comparison of the volume of a large sphere and a small sphere. Ask for likenesses and differences but end by focusing on volume -- larger volume and smaller volume.

Make a clay model of the smaller sphere, attach it with a thread, and submerge it using the same procedure used in Part C.

As before, when this has been completed and discussed, ask the children to order about four or more spheres from largest to smallest volumes using the water displacement techniques described above.

Part E: Ordering Samples of a Liquid Based upon Volume or Amount of Liquid

Assemble approximately six of the small transparent jars or glasses (all the same size), a pitcher or large jar, and food coloring or dye. Fill the pitcher with water and dissolve the food coloring or dye in it until the water is a rather deep shade. Pour a different amount of colored water into each of the jars.

Show the children two of the containers of colored water. Place them side by side on a horizontal surface. Ask the children to describe how the two objects are alike.

Now ask the children to tell you how the two objects are different. Ask them to use words that describe the differences.

COMMENTARY ON THE SEQUENCE

The spheres need not be all the same. Different sized balls, beads and marbles may be used, but the emphasis must be placed on volume, not the materials that the sphere is made of.

Emphasize the use of the terms larger volume and smaller volume when discussing the relative sizes of the two spheres.

The purpose here is to demonstrate again to the children another method of observing that smaller objects displace less water and larger objects displace more water.

Spheres that do not sink may have to be submerged by holding them under water with the points of pencils.

This part of the activity may be completed in one session. You may also wish to combine it with Part F and complete both in one session.

Have the children note that the jars are the same size and shape. They should also note that each jar contains a colored material. The materials are also liquids because they seem to flow and they take the shape of the jars they are in. Their surfaces are level, therefore they possess the properties of a liquid.

The children should state that one jar contains more liquid than the other jar, or they may state that one jar contains less liquid than

INSTRUCTIONAL SEQUENCE

Now place three of the jars on the horizontal surface. Ask if the jars are all the same size and shape. Ask a child to place them in order and to tell his reasons for ordering the jars the way that he did.

Repeat this procedure by placing the six jars on the surface and asking another child to order these and give his reasons for the method he used.

Part F: Ordering Samples of Sand Based upon Volume or Amount of Sand

Prepare approximately six small, transparent containers by putting a different amount of sand in each.

Follow the same general procedure as Part E with six containers of sand.

Part G: Preparing an Exhibit of Concepts Learned

Make a display of sets of materials used, and of additional sets of materials, some of which the children should bring from home. Suggest that the children practice ordering the objects in each set when there is opportunity to do so. Discuss each child's completed arrangement with him.

COMMENTARY ON THE SEQUENCE

the other. Each description is acceptable.

If they appear to be ready for it, you might talk about the amounts of liquid as being volumes of liquid. One jar has a greater volume of water in it than the other does.

The intent of this activity is to develop the ability to compare the amounts of water in similar jars, from most to least water by the process of ordering.

In addition to having the children describe amounts of water in terms of most water and least water, encourage them to use the expressions greatest amount of water and least amount of water.

This part of the activity is intended as an assessment of the children's understanding of ordering on the basis of amounts. Sand is appropriate for use since it packs into a container as liquids do. (It is called a fluid solid, while water is called a fluid liquid.) You may wish to use it during the same session as Part E, or you may want to allow a day or so to elapse before using it to assess their understandings.

The sets of materials should illustrate ordering on the basis of length, area, and volume or amount.

TOPIC 11: MEASUREMENTS

Activity 2: Measuring and Estimating Amounts

TEACHING OBJECTIVES

<i>Skills</i>	<i>Phenomena</i>	<i>Concept Goals</i>
Measuring	unit-measure of water	to introduce the concept of a unit amount of a substance
Observing	multiple unit measures of water	
Communicating (by recording)	pictorial representations of unit measures and combinations of unit measures	to contribute to the idea that unit quantities can be represented by unit spaces on graphs or worksheets

Key Vocabulary: measure, a measure

Materials:

4 cups or jars, transparent, 8 oz.
1 1 oz. cup, plastic or waxed paper (one measure)
1 wide-mouthed container of water, quart size or larger
1 bottle of food coloring or powdered dye
4 labels, gummed, or strips of masking tape
1 felt-tipped pen
For each child:
1 crayon
1 copy of worksheet, "HOW MANY MEASURES?"
For extending understandings of measures:
30 1 oz. cups, plastic or waxed paper
1-4 quart size or larger wide-mouthed containers of different colored liquids
30 8 oz. cups or jars, transparent
1-5 samples of pourable solids such as sand, salt, dry cereal, vermiculite, gravel and so on.

Preparation for Teaching: Add enough food coloring or dye to the water in the container so that it becomes a rather deep shade. Use the pen to mark the labels or pieces of masking tape, A, B, C and D and affix a label to each of the 4 cups. Place the container of water, cups A, B and C and the measuring cup where all the children may observe them without difficulty. Assemble the remaining materials and place them aside for use at the end of the activity. (NOTE: Save all of the materials from this Activity as they will be needed for Activity 3.)

INSTRUCTIONAL SEQUENCE

1. Developing an Understanding of "One Measure"

Ask a child to fill the small 1 oz. cup by submerging it in the container of colored water. Then have him pour the water from the (1 oz.) cup into cup A. Ask the children how much water cup A contains. Invite the same child to pour the measure of water from cup A back into the container of colored water.

Ask a second child to "put one measure of water into cup A," and then pour it back into the container.

Ask the children to tell about other kinds of measures they have used.

2. Representing "One Measure" of Water

Ask another child to put one measure of water into cup A. Now, sketch a cup on the chalkboard, similar to cup A on the Worksheet.

Distribute a Worksheet and a crayon to each child. Help the children identify cups A, B, C, and D on the Worksheet. Also, help them find the lines indicated by 1, 2, 3, and 4 on each of the four cups shown.

Ask the children to fill in the space on cup A on their Worksheets to show that there is one measure of water in cup A. Then, ask them to write the numeral "1" in the space before the word measure that appears below cup A on the Work-

COMMENTARY ON THE SEQUENCE

This activity should give the children practice in measuring, exploration of the concept of a measure, and practice in estimating amounts in terms of "how many measures." (Note that measuring "amount" can refer to how much in weight or how much in volume. In this activity amount is being used in terms of volume or "number of measures.") The activity may be completed in 1 or 2 sessions.

Accept the response "one cup." Indicate that the small cup is to be used for measuring a number of things from now on and that it is to have a special name, a measure or one measure.

You will probably want to repeat this process as many times as necessary until the children seem to understand that they are measuring water and that they are using a measure to do so. In this case, the measure is the small cup.

Examples might include measuring cups, teaspoons and tablespoons.

You will probably want to show the children how the spaces below the line labeled "1" on cup A can be filled in to indicate one measure of water.

Explain that each of the lines labeled "1" indicated one measure.

INSTRUCTIONAL SEQUENCE

sheets. Write 1 measure under the sketch on the chalkboard.

3. Representing More "Measures" of Water

Now ask a child to put two measures of water into cup B and then to pour the water back into the large container. Again, ask another to pour two measures of water into cup B.

Ask the children to compare the amounts of water in cups A and B.

On the chalkboard, sketch a second cup similar to cup B on the worksheet. Ask a volunteer to come up to the board and fill in the portion of the cup below the line labeled "2."

Ask the children to use their crayons to do the same to cup B on their Worksheets. Then ask them to write the numeral "2" in the space before measures under cup B on their worksheets.

In a similar manner develop an understanding of three measures of water. Turn the cups so that the labels are not visible, and tell the children that they will play a game called "Which Cup?" Indicate that while their eyes are closed, one of the three cups will be removed. When they are asked to open their eyes, they are to tell whether cup A, B or C has been removed and to give a reason for their answer.

Place cups A, B, C and D on the table. Invite one child to act as a helper. Ask the other children in the class to close their eyes and quietly tell your helper to put four measures of water in cup

COMMENTARY ON THE SEQUENCE

It might be wise to ask the children to put their fingers on the place where it says "1 measure" on their Worksheets. Be certain that all children understand this procedure at the beginning.

You will probably want to repeat this process until it is clear that the children understand that two measures of water are being used.

Point out that there is *more* water in cup B *than* in cup A, that there is *less* water in cup A *than* cup B, that there is a *greater amount* (volume) of water in cup B, and so on.

You will want to establish the fact that the line and its identifying numeral indicate two measures of water.

Develop the idea that referring to the amounts of water in the remaining cups and to the amounts indicated on their Worksheets will provide clues. Continue to play the game until mastery is achieved.

Estimating is introduced in this part of the activity. It gives the children the opportunity to form in advance some idea of the order of magnitude of measure. The intent is to give them some guidance

INSTRUCTIONAL SEQUENCE

D. Ask the children to open their eyes and estimate the amount of water in cup D. Ask them to give evidence for their estimates.

Have your helper mark the height of the water in cup D, and ask him to pour it back into the large container. Invite another child to add measures of water to cup D until the mark is reached.

After making sure that the children understand that there are now four measures of water in cup D, ask them to show four measures of water in cup D on the Worksheets.

4. Extending Understandings to Include Other Pourable Materials

Make a supply of water, jars and "one measure" cups (1 oz.) available so that children can practice measuring amounts of water. In addition, provide sand, cereal and other solids which may be poured and measured in the same manner.

COMMENTARY ON THE SEQUENCE

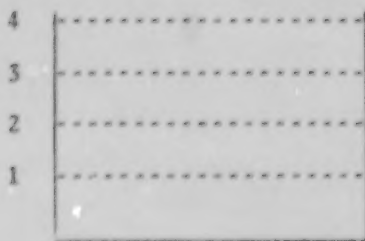
toward the eventual manipulation of numbers which will be developed in more detail in the upper grade sequence.

In this part of the activity, children will be able to determine whether their estimates were correct.

It is suggested that this part of the activity be as "free" as possible. Allow the children to work in groups or individually. Offer them a variety of as many liquids and solids as possible so that after this experience they have developed the understanding that certain solids, as well as liquids, may be measured in this manner.

WORKSHEET

HOW MANY MEASURES?



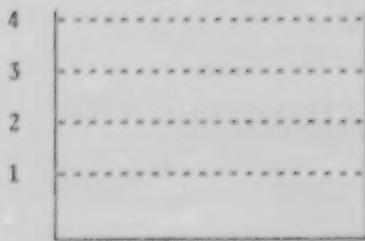
A

_____ measure



B

_____ measures



C

_____ measures



D

_____ measures

Selected Assessment Materials from the
Grade 1 Part of the Teacher's Guide for K-1

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TOPIC II: MEASUREMENTS

Teaching Objectives:

Comparing sizes and ordering groups by size, area, volume, or amount.
Ability to measure and estimate amounts.
When two samples of a substance are put together, the final volume is the sum of the original volumes.
Volume is conserved regardless of shape.
Any container can serve as a unit of measurement.
Measurement of length can be performed with arbitrary units, but the same one must be used to make comparisons.
Thermometers are used to measure how warm or cold something is.

You may wish to repeat the assessments provided for Kindergarten Topic III (Making Comparisons) in addition to the new assessments for the present topic. The concept goals are similar.

The Topic II assessments are in two parts. In Part A, the child is presented with various problems calling on his ability to order objects, e.g., "Draw a circle around the tallest boy." Part B deals with measurement and conservation with questions like "Draw a circle around the object which would be best for measuring amounts of water."

The administration time for both parts is 10-15 minutes. This can be completed in one class session if desired. The individual assessments for Topic II appear in a separate section following the screening assessments.

Part A - Instructions

Preparation:

Reproduce pages 1,2, and 3. Collate.

Distribute booklets to the class and check to see that each child has a crayon with which to mark his answers.

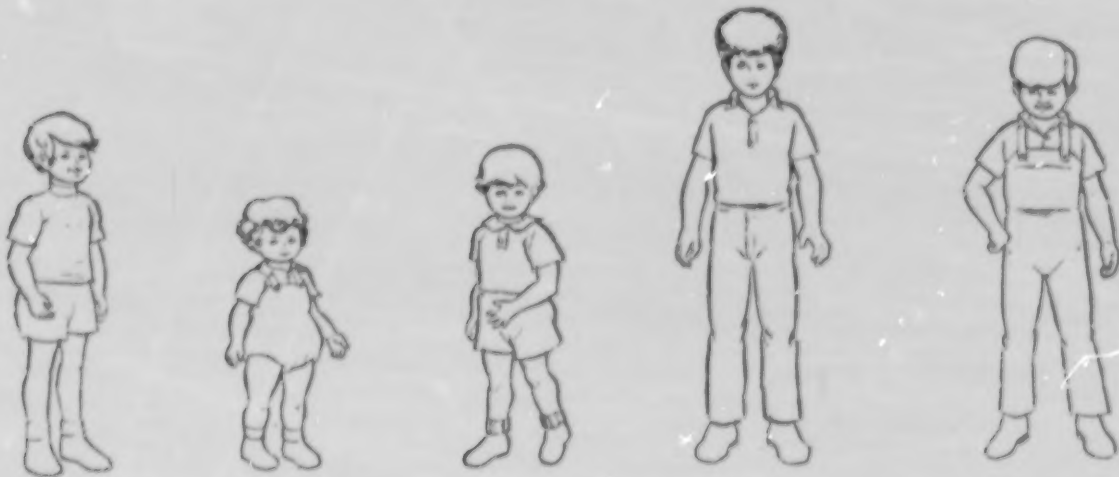
Begin the assessment by asking the children to put their names on the blank provided. Check quickly to make sure all the children have their names in the correct place. (You may want to hold up a copy of the booklet and show the children where their names belong.)

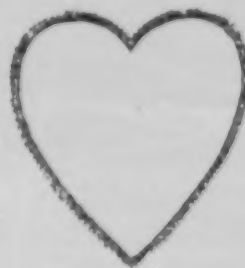
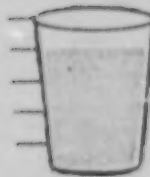
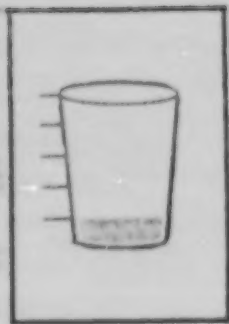
Recall with the children that objects which are similar can be put in order using one of their properties to decide on the order. Bring the attention of the children to the example at the top of the first page. Ask them to draw a circle around the longest nail. Pause for 20 seconds. Ask them to draw a line under the shortest nail. Check quickly to see that all the children have responded correctly; dashed lines have been provided for guidance. Tell the children that on each sheet there will be three groups of pictures. For each group of pictures they will be instructed as to what to do. Explain to the children that they should listen very carefully to each question because sometimes they will be asked to do very different things.

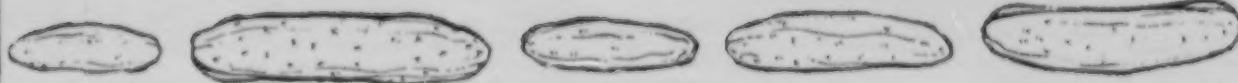
The assessment may now begin. Refer to problems as *top*, *middle*, or *bottom* of the page. For the questions on pages 1 and 2, pause 20 seconds between the two parts of the question. For the questions on page 3, pause about 25-30 seconds for the children to mark their responses.

- p. 1 top Draw a circle around the longest nail. Draw a line under the shortest nail. (This is the example.)
- mid Draw a circle around the shortest boy. Draw a line under any boy who is not the shortest or the tallest.
- bot Pretend you had a box of cookies, all the same size. Draw a circle around the plate on which you can place the most cookies. Draw a line under the plate on which you can place the fewest number of cookies.
- p. 2 top The first glass which is in a box contains one measure of water. Draw a circle around the glass which contains 3 measures of water. Draw a line under the glass which contains 4 measures of water.
- mid Draw a circle around the largest valentine shown. Draw a line under the smallest valentine.
- bot Draw a circle around the tree which looks as if it has the most leaves. Draw a line under the tree which looks as if it has the fewest leaves.
- p. 3 Remind the children that they will be asked a different kind of question.
- top The three blocks are in order from smallest to largest. Look at the block in the circle. We want to put all the blocks in order. Make an X on the line to show where the block in the circle would fit.
- mid Look at the cucumbers. Draw a circle around each cucumber that is longer than the cucumber in the circle.
- bot Look at the boys. They are standing in order from shortest to tallest. There is another boy standing in the circle. We want to put him in his proper place in line. Make an X on the line to show where the other boy would fit.

NAME _____







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INDIVIDUAL ASSESSMENTS

Length

Present the child with several pencils of different lengths standing upright. (This can be accomplished by using clay as a base and sticking the pencil into the clay so it is vertical.) Ask the child to make comparisons of taller and shorter with different pairs of pencils. The child can then be led to order three pencils at the same time. This can be repeated with different numbers of pencils.

To assess the child's understanding of the concept, problems similar to the screening assessments may be used. Arrange objects which differ in height on the child's desk, leaving one out. It is the child's task to place the object in its proper place in the order.

Area

To aid the student who has not mastered the material from the activity, a repetition of the activities on an individual basis is recommended for this section.

Individual assessments might include the following: Present the child with four or five books of different sizes. (Try to make sure the thicknesses are the same so that the child will not be distracted by this dimension.) Ask him to order them from largest to smallest. You may say "From the one which covers the most space to the one which covers the least space." Present the child with sheets of paper, each one the same length, but different widths. First present them two at a time, each time asking him which one covers the most space (or the least space). After several comparisons have been made, you might ask the child to order the sheets from smallest to largest. (Again, the "covering space" idea may be used.) A third activity would be to have the child draw simple pictures of whatever he wishes and instruct him to draw a larger object, an object which is larger than the first, but smaller than the second, etc.

Volume

Again, it is recommended that the original activities be repeated on an individual basis for those students who need more practice in mastering the concept.

Individual assessment of the material might include the following activities:

You might present the child with several different sized cups or glasses, or different shaped glasses and jars, if possible, with the same diameters, and have him guess which one will hold more water. This can be tested by pouring water to the top of the smaller cup and then transferring the water to the larger cup and noting that the water does not fill the larger cup. Or water can be poured into the larger cup first, and the child will note that when he tries to pour this water into the smaller cup there is not enough room.

Selected Activities from the
Teacher's Guide for Grade Two

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TOPIC I: WHOLES, PARTS, AND PATTERNS

Activity 1: Seed and Plant Patterns

All of the information necessary for the development of a green plant is contained within the seed. The information will be translated into a specific pattern of structural and functional organization when the seed germinates and growth begins. Although different environmental conditions can modify these patterns, a tomato seed, for instance, can never germinate and develop into a radish plant, no matter what environmental conditions are imposed. It will always produce another tomato plant, if it produces anything at all. Obviously, then, the information contained within a radish seed must be different in its details from that within a tomato seed. Consider the radish and tomato plants, however. When one observes different plants like these, one is impressed more by the overall similarities in organization than by the differences. Therefore one can infer that much of the information concerning structural and functional organization must be basically similar for all green plants.

The common pattern of organization that is most easily discernible by children is the spatial arrangement of the principal plant parts--the leaves, stem, and root system. These parts are all necessary for normal growth. The discovery of these phenomena will allow the children to develop the understanding not only that some plants exhibit the same structural pattern, but that the parts interact to form a system. Thus they should begin to comprehend that an organism is greater than the simple sum of its parts.

TEACHING OBJECTIVES

Skills	Phenomena	Concept Goals
Inferring (from)	the pattern of plant development of a variety of seeds	that there is a basic similarity in the structural organization of each type of plant.
Inferring (from)	the different plant patterns emerging from	that a specific seed contains the information required for its specific

Skills	Phenomena	Concept Goals
	each of the different seeds	plant.
Experimenting	by removing one of the plant parts (leaves, stems, or roots) during growth	(to realize) that each plant part is necessary for normal growth.
Interpreting	the evidence from the above experiment	(to introduce the idea that) a plant is more than the mere sum of its parts. It is an interacting and interrelated system.

KEY VOCABULARY: No new terms.

MATERIALS AND EQUIPMENT:

For each pair of children you will need:

- 4 pieces of heavy blotter paper or nonglossy cardboard, each about 3 by 3 in.
- 10 each of four different kinds of seeds: for instance, corn, radish, red kidney or mung beans, and pumpkin or squash seeds
- 4 pieces of plastic wrap, each about 6 by 6 in.
- 8 plastic or paper cups to be used as potting containers--cottage cheese or other similar containers
- potting soil (amount depends on number of children and size of containers)
- 1 pair of scissors

You will also need:

- 4 extra potting containers and soil
- 4 each of four different kinds of seeds (see above)

PREPARATION FOR TEACHING:

Approximately two to three weeks in advance of the start of the Activity, plant corn, radish, red kidney or mung beans, and

pumpkin or squash seeds in potting soil in four separate containers. If these seeds are not available, any reasonably sized seeds can be substituted but try to have four that do not appear similar. Put at least four seeds of the same kind in each of the containers depending on their size. When the seedlings are well-developed, the Activity may be started.

ALLOCATION OF TIME:

The children will need about four hours, extended over a period of time, to complete both parts of this Activity. Since it will take a few weeks for your display seedlings to become sufficiently established to begin, you might go on to the second Activity while they are growing.

Part A: The Information Content of a Seed

INSTRUCTIONAL SEQUENCE

1. Give each pair of children a mixture of seeds containing at least eight of each kind: corn, radish, squash or pumpkin, red kidney or mung bean. They should separate the mixture into its component seeds and indicate how they did so.

2. Have the established seedlings in full view of the class. Call attention to the four groups of plants, identify them by name, and tell the children that the plants were grown from seeds like the ones they themselves have. Ask them which seeds they think would develop into which plants. Then ask how they could find out.

COMMENTARY ON THE SEQUENCE

It is suggested that the children work in pairs but they could also work individually or in larger groups. You may want to adjust the quantities of materials according to the decision you make.

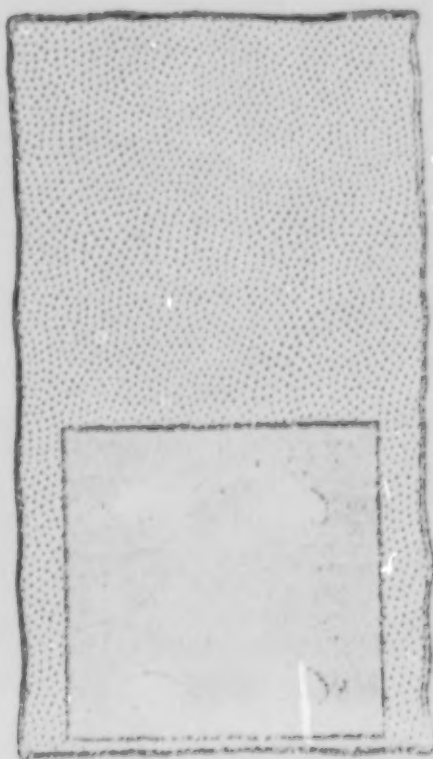
Classifying the seeds into groups will help the children focus on the specific properties of each seed type--their color, shape, size, etc. It will also reinforce the work done in classifying objects in Topic I of Grade 1.

There is no way to tell from just looking at a seed which kind of plant it might produce. The children may know this from prior experience. The way to find out how the seeds will develop is to plant them and then watch them grow.

INSTRUCTIONAL SEQUENCE

3. The children can follow the germination and subsequent development of each kind of seed by doing the following:

Each pair of children should take four pieces of nonglossy cardboard or heavy blotter paper, about 3 by 3 inches, and soak them in water. Four pieces of plastic wrap, one for each square of cardboard, should be spread out on the desk. (The plastic should be at least twice as big as the cardboard so that it can be wrapped around the board.) Set each piece of wet cardboard near one edge of a piece of plastic, as shown in the diagram below.



COMMENTARY ON THE SEQUENCE

Start this work on a Monday or full germination will not be observable by the children. During the week, they should observe the germination patterns of the different seeds carefully. You may wish to review the germination activities in Grade 1 where the criterion for the onset of germination was established as that time when the first bit of root emerged from the seed.

Using four seeds will make it probable that some will germinate. If they use only one of each kind, they may not select a living seed.

The children will probably remember from their earlier experiences that water is essential for seed germination. If they question the use of water, it would be wise to set up several dry "control" systems. (Such seed systems would be the same except that the blotter paper or cardboard would not be soaked in water.) On the other hand, if the children are thoroughly familiar with the idea that water is essential, setting up dry controls might detract unnecessarily from the major focus of the activity--i.e., watching the formation of developmental patterns from the seeds.

INSTRUCTIONAL SEQUENCE

They should then put four seeds of the same kind on each board or blotter and wrap the plastic over, and then underneath, the system of seeds and blotter.

4. Immediately following the preparation of the seed cards, have the children plant four of each kind of seed in some potting soil. Use cottage cheese containers or other suitable plastic or paper receptacles. For each kind of seed, plant two in one container and two in another. You will need eight containers for each pair of children. To remind them of what seed type was put in each container, they can tape a seed of the same kind to the outside.

5. Keep track over the first two to three days of what happens on each of the cards and in each of the containers. In the light of their observations, ask the children whether they think the same events are occurring in the soil as are occurring on the cards. How could they find out?

6. Each day the children should try to predict which seed will develop into which plant. You may do this by having the children place their card systems at the end of each day on the

COMMENTARY ON THE SEQUENCE

The children should try to water each of the cups identically. There will be too many plants for the current investigation, but these same plants will be used in Part B of this Activity.

During the week keep the seed systems at the desk or tables where children are working so they can observe any changes that occur from time to time. When the seeds begin to germinate on the cards, no changes will be apparent in the containers. However, germination is occurring in the soil as well and the children may discover this by carefully "digging" for one seed and observing it. If they do this carefully, its growth and development will not be seriously interrupted. If the disturbed seedling, or any others, fail to develop, discuss what might have happened with the children.

At first there will be great disagreement. In fact, their predictions will be little more than guesses. However, as the seedlings develop, and more and more information is

INSTRUCTIONAL SEQUENCE

table next to the plant into which they predict it will grow.

Toward the end of the week, again discuss with the children the differences between the "card" and "soil" systems.

7. At this point the card systems can be discarded but the children should continue to predict into which plants their young seedlings planted in soil will develop. (They may want to select a few of the seedlings on the card for transfer to soil to see whether these will develop normally.)

How are the different kinds of seedlings alike? How are they different?

COMMENTARY ON THE SEQUENCE

accumulated, more and more of the children will make the same predictions.

At first, all the predictions will be made on the basis of the developmental patterns on the cards. Within one week, however, the pattern of development on the cards will become distorted because of mechanical restrictions on the growth of the seedlings. Thus, although there are many similarities between the patterns of development of the same kind of seed on the card and in the soil, they are not identical.

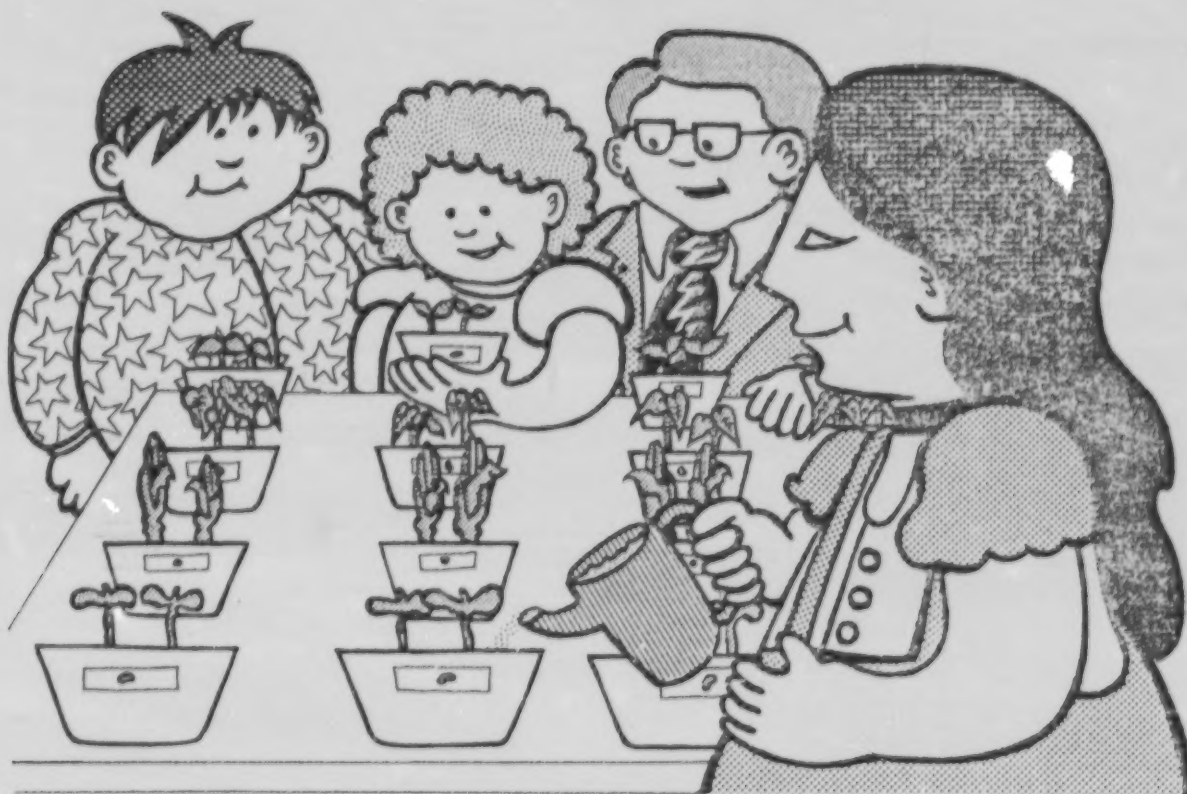
The discussion should emphasize the following two ideas: First, the "card" system was useful for observing the germination of the seed and early development of the seedling, especially the development of the young roots. The "soil" system, however, is more suited to studying later developmental changes. Second, different environments may influence the manner in which the plant will grow.

The children should be encouraged to look at the developing patterns of organization closely. (You should be about eight to ten days into the activity at this point.) Even though the seeds and seedlings are different in details of appearance, the basic parts of each plant are the same and the parts have the same spatial arrangement with respect to each other. The roots are in

INSTRUCTIONAL SEQUENCE

COMMENTARY ON THE SEQUENCE

the soil, the stem is attached to the roots, and the leaves are attached to the other end of the stem. In no case are leaves and roots directly connected.



Do any of the radish seeds develop into corn plants? Do any of the pumpkin seeds develop into radish plants?

The children will also find that radish seeds always grow into plants like those identified as radish earlier; corn seeds give rise to those identified as corn, etc. The

INSTRUCTIONAL SEQUENCE

COMMENTARY ON THE SEQUENCE

information for development must be in the seed. Each seed apparently has the information for a particular kind of plant and no other.

It would provide a valuable additional learning experience if a few of each type of plant were allowed to grow to maturity in the classroom. They would need to be transplanted, of course. This would allow the children, even though by then they would be engaged in other activities, to observe that "radish plants" do indeed produce radishes, "bean plants" produce beans, etc.

Part B: Focus on the Parts of the Plants

1. While discussing the idea that seedlings and older plants have roots, stems, and leaves, encourage the children to speculate about which parts of the plant might be needed for normal growth. You might want to ask questions such as the following:

- Will the plants continue to grow if one of the leaves is removed?
- Will the plants continue to grow if *more* than one leaf is removed?
- How many leaves can be removed without killing the plants?
- Do the plants need roots in order to grow?

Note that this activity builds on the work with plants in Topic II of the Kindergarten sequence.

INSTRUCTIONAL SEQUENCE

- How much of the root system does the plant need in order to grow?
- Is the stem necessary for normal growth?

2. Discuss with the children how they might find answers to these questions, using their plants.

3. The children should make observations of the effects of total and partial removal of the plant parts from the different plants over the next several days, pool their observations, and then analyze them through discussion.

COMMENTARY ON THE SEQUENCE

Have the children explain what their individual approaches might be. Basically, it will be necessary to cut off or otherwise remove parts of the plants in a *systematic fashion* and then observe them over a period of time to see what happens. Try to arrange things so that: a) Each child or group has a control plant, for comparison, which will not be cut up. b) The range of activities for the class will include the total removal of the stem and the partial and total removal of both the leaf and root systems for at least two, and preferably all four, different species of plant. (Each pair of children within the group could study a different effect.)

The children's observations should lead to the following conclusions:

- The plants need leaves in order to grow (normally).
- The plants need roots in order to grow (normally).
- If only a *small* portion of the leaves or roots are removed, they will grow back and the plants will live.
- Since the stem supports the leaves, it is needed for

INSTRUCTIONAL SEQUENCE

COMMENTARY ON THE SEQUENCE

the plant to grow (normally).

- The above pattern is the same for each of the kinds of plants investigated.

The concluding discussion should focus on the idea that, although a plant can be described as being a system composed of leaves, stems and roots, if you remove one of the parts, the other parts suffer. Therefore, there must be some sort of interaction and the plant is more than just the sum of its parts.

Selected Assessment Materials From
The Teacher's Guide for Grade Two

TOPIC I: WHOLES, PARTS, AND PATTERNS

Screening Assessments

The concept goals for Topic I are summarized below. In the Teaching Objectives for each Activity, the corresponding concept goals typically incorporate the content of the Activity. In contrast, the statements below are more general--you should not expect to find a close correspondence. The assessments are aimed at evaluating the child's grasp of the essence of the concept, often in terms having a less than obvious relation to the specific content of the Activities. This level of abstraction is intentional. We wish to assess the child's knowledge of and ability to apply the more abstract idea, rather than to assess only his memory for specific prior experience.

1. Objects and/or their parts are sometimes described in terms of functional properties.
2. Objects are made up of discrete parts.
3. Living objects are both highly ordered and highly organized.
4. Some non-living solid objects show a high degree of order.

Part 1 of the screening assessment tests for mastery of the part-whole concept, Part 2 deals with pattern and order, and Part 3 deals with the concept of functional parts. All three parts may be administered in one class session--the total assessment should take no more than 15 minutes.

Apple



Bat



Cup



Dog



Glass



Hat



Iron



Jet Plane



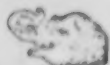
The assessment pages are ordered consecutively for an entire Topic. In order to help the children find the page that they should be working on, the symbol system shown at the left has been developed. One of these picture-symbols, which the children will easily recognize, appears in the upper-right-hand corner of each assessment page. The symbols are

Elephant

Kite

in alphabetical order so that you can maintain the correct order in collating.

Flower



The assessment pages may be collated in groups, Part 1, Part 2, etc.,--sometimes children appreciate the change of pace afforded by collecting one set of papers and passing out the next. The assessments may also be distributed as a complete set for the Topic. In either case, have the children write their names in the appropriate place on the first page.

In these assessments, suggested instructions to be read to the children appear in capital letters. They may be read verbatim or, if you feel some change is necessary for your group, they may be modified. In that case, please try to stay as close to the intent of the given instructions as you can. The assessments and scoring guide have been prepared with these instructions in mind.

PART 1

Pages A and B

Direct the attention of the children to the page with an apple in the upper-right-hand corner. Have them look at the objects on the top part of that page.

SOMETIMES OBJECTS ARE MADE UP OF SMALLER PARTS. LOOK AT THE BIG OBJECT. IT IS MADE UP OF SMALLER PARTS. BELOW THE BIG OBJECT ARE THREE SMALLER ONES. DRAW AN X ON THE OBJECT WHICH IS PART OF THE BIG ONE. Pause 30 seconds. Draw a triangle on the chalkboard. YOU SHOULD HAVE DRAWN AN X ON THE TRIANGLE BECAUSE THE TRIANGLE IS PART OF THE BIG OBJECT. ON THIS PAGE AND THE NEXT, LOOK AT EACH BIG OBJECT AND DRAW AN X ON ONE OF THE THREE OBJECTS BELOW IT WHICH IS PART OF THE BIG OBJECT.

Allow about three minutes for the children to complete pages A and B. If they received the assessments in their entirety, tell them to stop after completing the page with the bat and wait for new instructions.

PART 2

Pages C and D

Direct the attention of the children to the top of the page with the cup.

THERE ARE TWO SETS OF CIRCLES. DRAW AN X ON THE SET OF CIRCLES WHICH ARE IN MORE OF A PATTERN.

After the children have marked their responses, ask some of them which set they chose, and why. If any children happen to find some reason for calling the set on the left a pattern, it should be pointed out that the pattern on the right is more obvious and easier to see, so it is in "more of a pattern."

Ask the children to do the same thing for the rest of the problems on this page and for those on the next (Dog) page--that is, draw an X on the set which is in more of a pattern.

Allow about five minutes for the children to complete their responses. Tell them to stop after completing the page with the dog and wait for new instructions.

PART 3

Page E

Discuss with the children the idea that large objects are sometimes made up of parts. Continue with the idea that sometimes the smaller parts are needed by the larger objects. Give examples: a car can't run without the motor and a television won't work without a knob to turn it on.

Write the words *ride* and *can't ride* on the chalkboard with a box under each, as shown on page E. Then ask the children to look at the tricycle in the upper left picture on the page with an elephant. (Hold up an Elephant page and point out the picture.)

THIS IS A PICTURE OF A PERFECTLY GOOD TRICYCLE. ANY ONE OF YOU COULD RIDE IT. IF SOME PARTS OF THE TRICYCLE WERE TAKEN AWAY, YOU WOULD NOT BE ABLE TO RIDE IT; IF OTHER PARTS WERE TAKEN AWAY, YOU COULD STILL RIDE IT. IN THE REST OF THE PICTURES, ONE PART OF THE TRICYCLE IS MISSING. THE MISSING PART IS COLORED DARK. UNDERNEATH EACH PICTURE ARE TWO BOXES. ONE BOX SAYS *ride*. IF YOU THINK YOU CAN STILL RIDE THE TRICYCLE, COLOR IN THE BOX WHICH SAYS *ride*. (Point to the word *ride* on the board.) THE OTHER BOX SAYS *can't ride*. IF YOU THINK YOU CAN'T RIDE THE TRICYCLE WITH THE DARK PART MISSING, COLOR IN THE BOX WHICH SAYS *can't ride*. (Point to the words *can't ride* on the board.)

Again, direct the attention of the children to the picture at the upper left. COLOR IN THE BOX WHICH TELLS IF YOU *can ride* OR *can't ride*. (Pause.) YOU SHOULD HAVE COLORED IN THE BOX WHICH SAYS *ride* SINCE THERE IS NOTHING MISSING FROM THE TRICYCLE. NOW COLOR IN THE BOX WHICH TELLS IF YOU CAN *ride* OR *can't ride* FOR THE OTHER FIVE PICTURES ON THE PAGE. Allow about three to five minutes for the children to respond.

APPENDIX E
EXHIBITS FROM THE TEACHER'S GUIDES
Grades Three through Five

A Sample Activity From
Teacher's Guide for Grade Three

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Activity 5: Where Did the Green Go?

In Activities 3 and 4, the children found that some, but not all, substances interact with water to form solutions. The process of forming solutions, or dissolving, evidently results in very tiny particles because they can pass through a very fine sieve--filter paper. Although it would appear that the dissolved particles must all be the same color as that of the solution they produce, this is not always the case. The children discover this by allowing colored solutions to move within filter paper, and in the second Part of the Activity, through chalk. Both materials are used to separate the different colored components of solutions.

Evidence obtained from this final Activity of the sequence adds to the child's developing concept that materials are made up of particles and that the particles are not necessarily identical--they may possess different properties. Each component part may be a different color. Thus the observations which children make of the interaction of colored solutions and filter paper, and the interactions of colored solutions and chalk, add to their developing concepts not only of interaction and change, but also of the structural units of matter.

MATERIALS AND EQUIPMENT:

- 1 bottle of green liquid food color
- 1 eyedropper
- 2 glass jars or transparent plastic cups, at least 4-oz to 5-oz (150-ml)
- 1 stirring spoon
- 1 coffee-maker filter, or a sheet of chemical filter paper, about 10-in. to 12-in. (25-cm to 30-cm) in diameter
- 1 roll masking tape

In Part A, for each child or small group of children, you will need the following for each colored solution to be analyzed:

- 1 plastic or waxed paper cup, 1-oz (approximately 30-ml)
- 1 cotton swab

- 1 tall, transparent glass jar or drinking glass, at least 6-in. (15-cm)
- 1 strip of coffee-maker or chemical filter paper, 1-in. by 7-in. (2-1/2-cm by 18-cm)
- 1 paper clip

In Part B, for each child or small group of children, you will need a ruler. In addition you will need the following for each colored solution to be analyzed:

- 1 plastic or waxed paper cup, or other small transparent container with a flat bottom surface, 1-oz (approximately 30-ml)
- 1 piece of unused, soft (dusty variety) chalk
- 1 flat, colorless toothpick
- 1 bottle of blue food color

You may also want to obtain a selection of the following optional materials:

Sheaffer Skrip No. 62, washable black ink (red, blue, and yellow components)

Parker permanent black ink (purple and yellow components)

Sheaffer permanent blue-black ink (blue and red components)

Sheaffer permanent red ink (one component, red)

Sheaffer washable blue ink (one component, blue)

Red food color (one component, red)

Yellow food color (one component, yellow)

PREPARATION FOR TEACHING:

Before beginning the initial demonstration, pour about 100 ml (3 to 4 oz) of water into one of the 150-ml jars, which has been carefully cleaned.

If the labels on the bottles indicate the component colors in

the food colors, remove the labels. After children have observed the separated colors, they might use the information on the labels to confirm their findings.

For each group of children, put a few drops of green food color into a small 1-oz cup. For Part A, the strips of filter paper should be cut a little longer than the height of the tall jars or glasses. Before class, pour water into the jars to a height of about 1/2 in. (1 cm). More water can be added later if necessary. Before beginning Part B, pour 1/4 in. (5 mm) of water into the small, flat-bottomed containers.

ALLOCATION OF TIME:

The children will need two hours, or more, exclusive of the Extended Experience, to complete this Activity.

PART A:

TEACHING SEQUENCE

1. Show the children the jar containing the 100 ml of water. Ask one of them to add about 20 drops of green food color to the water, drop by drop. They should use the spoon to stir the mixture gently after each drop is added.

- What happens as drops of food color are added to the water?

Ask someone to hold the jar between the group and a window or an electric light.

- Can you see any particles of the green food coloring?

COMMENTARY

The introductory parts of this Activity, leading to chromatographic separation, are based on the children's prior experience with making solutions and with filtering. They serve as a quick review and as a means of getting them intrigued with the possibility that an apparently homogeneous solution may be made of separable components.

The children should observe that the green color tends to spread out from the spot where each drop enters the water. Each time the system is stirred, the liquid becomes a darker green.

When this is done it is possible to get a clearer view of the mixture. The children should not be able to see any of the particles of coloring material and should recognize

TEACHING SEQUENCE

- What is such a clear liquid mixture called?

When it is established that the individual particles of the colored material cannot be seen, ask the children to predict what will happen when they filter the solution.

Ask two children to use the technique introduced in Activity 3 to filter about 2 tsp (10 ml) of the green solution into a clean jar.

Ask the children to describe their observations and to explain what they think might be happening.

COMMENTARY

it as a solution. (If there are particles of dust in the mixture, it may be confusing. Thus it is important to keep all equipment clean.)

It should be noted that food coloring is already in the form of a "concentrated" solution. The solution simply becomes more dilute when mixed with more water.

Many of the children should recall that solutions will go through filter paper. Thus, they should expect the unseen particles to go through the paper with the liquid. This is what happened when they filtered the red solution of cobalt chloride in Activity 3.

Filter paper, rather than paper toweling, should be used throughout this Activity because the colored bands indicating the different components appear less diffuse and are thus more easily recognizable. Paper toweling is adequate for gross, initial observations (see Activity 6 of Topic I in Grade 2) but the children can now refine their techniques and observations as they go on to explore chromatographic effects in different media.

The green color comes through with the liquid, showing that particles of the coloring material were small enough to pass through the filter paper. This is a property of a solution--its component parts can pass through filter paper.

TEACHING SEQUENCE

If they could see the particles, what would they expect their color to be?

When the solution has filtered through, ask one of the children to open up the filter paper and hold it up for all to observe.

- Did all of the green substance go through the filter paper? Ask different children to discuss what they observe.

Use masking tape to attach the filter paper to a ledge, such as the chalkboard trough. Ask the children to observe it from time to time as it dries.

- If the solution was green, where did the yellow come from?

2. Suggest that the children examine the process more closely to see if they can explain what is happening. This time, however, rather than pouring the colored solution into a filter, water will be allowed to travel up strips of filter paper upon which a small dab of the colored solution has been placed.

Distribute to each child, or small group of children, one of the tall transparent jars or drinking glasses with a small amount of water in the bottom of it. Also give each

COMMENTARY

Considering that the solution itself is green, children will undoubtedly expect that the tiny particles would be green also.

The purpose of this part of the sequence is to show that the colored component enters the paper along with the water. Since some liquid is left in the filter paper, some of the coloring material is also left--a green circle will be obvious to all. It is possible that some may even observe a yellow color at the edge of the circle. If no one observes this, do not pursue it.

When it is completely dry, children should be able to see that a yellow colored part has separated. In some cases, when you open up the filter paper, the liquid that remains inside the tip of the cone will flow quickly to the edge of the paper. When the paper dries there may be a spot or two at the very edge that appears blue.

This is the actual technique of liquid chromatography--a liquid, in this case, water, travels up a medium carrying other substances with it. The different colored components in the solution will separate out as the water travels up the paper.

TEACHING SEQUENCE

a strip of filter paper, one of the 1-oz cups containing green food color, and a cotton swab.

Demonstrate how to place a small dab of green food color near the end of the strip of filter paper. This is to be done with the cotton swab after the tip has been dipped into the food color in the 1-oz cup.

Distribute the paper clips and show the children how to straighten them so that they can be threaded through one end of the paper strip. As shown in the diagram, the ends of the straightened clip can then be used to support the paper strip so that it hangs freely inside the jar.

Before children thread their straightened clips through the upper end of the strip, have them hold the strip on the outside of the glass to locate the place where the clip should be inserted in order that the lower end of it will be in the water. The colored dab should be at least 1 cm above the level of the water.

Caution children not to let the water in the bottom of the jar directly touch the colored dab on the strip of filter paper. Nor should the strip cling to the walls of the jar.

The children should observe

COMMENTARY

The dab of green food color should be placed about 2-1/2 in. above one end of the paper and should be about 1 cm in diameter. (A review of the centimeter scale may be necessary even though the children may have been introduced to it in Topic II of Grade 2.)

The cups of food color should be saved for use in Part B of this Activity.

If you think your group might have trouble straightening the paper clips, you could do this for them in advance.



Within one minute the water

TEACHING SEQUENCE

what happens as the water travels up the strip of paper through the green dab.

After the separation has taken place, ask the children to tell why the separation takes place.

3. What would happen if the bottom of the strip of filter paper were left in the water? The children might be helped to consider this question if it were phrased as follows.

- What color would reach the top first?

COMMENTARY

will start to travel up the paper and through the green dab. Within about 10 minutes, as the water continues to travel, the colored material from the green dab will begin to separate into a blue and a yellowish-green component. The blue component travels ahead, leaving a mixture of blue and yellow behind it. The blue and yellow together appear yellowish green.

After the colored material has traveled with the water about three-fourths of the way up the paper, have the children remove the strip from the jar. They should use the piece of masking tape to attach the wet strip to something where it can hang freely until it dries. After the strip has dried, the children can mark the piece of masking tape with another dab of the original food color, write "green food color" or "G.F.C." on it, and save it for future reference and comparisons.

The separation of the different components takes place because they travel up the paper at different rates. Just as when a faster runner gradually gets ahead of a slower runner even though they both left the starting point together, the blue particles gradually outdistance the yellow.

TEACHING SEQUENCE

- What would happen when the other(s) "caught up"?

After making their predictions, the children should try it. A different strip of filter paper should be used so that the original one can be kept as a record to compare with the separations obtained from other colored solutions.

At the conclusion of this Part of the Activity, encourage the children to recall their experiences with colored mosaics in Activity 1. Ask them to compare what they found there with what they found here.

COMMENTARY

They will find that the green color will be produced once again, if the bottom tip of the paper stays immersed in the water for about 1-1/2 hours. (It should be noted that reproduction of an original color from separate components will take place only if all components are soluble in water--that is, if all components move up the paper with the water.)

Reforming of the original green color should provide some evidence that the green coloring wasn't "changed" but just separated into its components. Sometimes children think that the paper "interfered with" or interacted with the green food color and "made it" blue--that the blue was a new and different material. In Part B of this Activity they will have an opportunity to do the same reforming using the medium of chalk.

The mosaics were formed by using small pieces of material of different colors. However when a mosaic was viewed from a distance it appeared to be one color, different from that of any one of its parts. Now they have found that this green food color is made up of at least two component particles, blue and yellow. When they are together in a solution, it appears to be green.

TEACHING SEQUENCE

COMMENTARY

PART B:

4. Give each child a piece of chalk. Tell them that you would like them to find out if chalk could be used to separate the component particles in the green solution.

- In order to use chalk in this way, what property must the piece of chalk have?

Next, distribute the following to each child or small group of children: one 1-oz container (to which you have added a small amount of water), a flat toothpick, a ruler, and samples of green food color.

Ask the children to lay their pieces of chalk against their rulers so that one end of the chalk is at the beginning of the centimeter scale on the ruler.

Now have them find the 1-cm mark on the ruler. They should dip the wider end of their toothpicks into the green food dye and mark a band all around the chalk 1 cm from the end of it. The band should be about as wide as the toothpick.

Have the children carefully insert the marked ends of the pieces of chalk into their 1-oz cups or jars so that the chalk

Many suggestions may be given but the important one is that water must travel upward through it. Water will readily travel upward in soft, dusty chalk, as the children will discover.

If the 1-oz containers do not have flat bottoms, substitute baby food jars or other similar transparent containers. The containers need to be flat so that the pieces of chalk can stand upright in them.

The children will probably have to dip their toothpicks into the solution several times in order to encircle the piece of chalk completely.

Within a minute or two they should observe the band of dye on the chalk getting wider. Then the band will start to

TEACHING SEQUENCE

stands upright and observe what happens. The colored band should be above the water level in the cups.

After 10 to 15 minutes they should remove the chalk and pour the water out of the cups. The chalk should be replaced in its original position inside the empty cup. Identify the food color by marking the top of the chalk with a pencil. The cups can be kept on desks or other places where children can periodically observe what's happening.

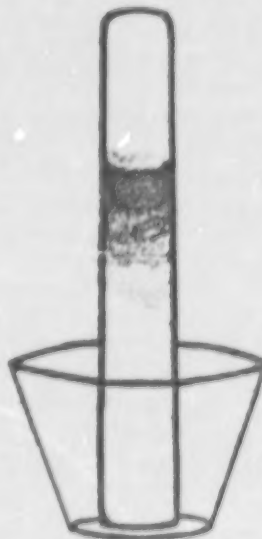
Direct attention to the chalk after it has stood for at least one hour. (This may be done the following day if it is more convenient.)

The children should compare their records of separation of green food color in filter paper with the separation that has taken place in the chalk.

COMMENTARY

travel upward with the water.

Since there is still a great deal of water within the chalk, the dye-solution will continue to travel up the chalk even when the remaining water is removed from the cup. By the end of an hour or so, it should be very obvious that the green food color has separated into two components: There should be a clear band of yellow at the upper part of the chalk and a band of blue beneath it. The yellow may be faint but it is definitely noticeable.



They should note that the yellow component has traveled ahead of the blue in chalk, whereas the blue component traveled ahead of the yellow in filter paper. Note also that the distinction between the

TEACHING SEQUENCE

- Based upon this evidence, what statement can be made about the interaction of solutions of food color and water with different media?

5. Have the children try blue food color, using the same technique as with the green food color.

- Which traveled faster, the blue material or the red material?
- Which would you expect to travel faster in filter paper? Have them repeat the preceding techniques using blue food color, water and filter paper.

EXTENDED EXPERIENCES:

There are several ways in which this Activity can be extended. The following are two avenues the children might like to explore:

1. Pieces of chalk with green (or blue) colored bands around

COMMENTARY

yellow and blue is much clearer in the chalk.

Solutions of food color appear to interact differently with different media.

Encourage the children to make predictions based on their experience with the green food color.

You may decide that it would be educationally desirable for all children to become involved as they did with separating the green food color. On the other hand, you may feel that it would be a better use of time if only two or three analyses were made and the results shared with the class. In any case, they will find that blue food color separates into blue and red components.

The red moves ahead of the blue.

The children have no sure way of knowing until they have tried it. However, they may suspect that the opposite will happen--that the blue will move ahead of the red. When they test their prediction, they may be quite excited to find they are right.

them could be left in the water for longer periods of time.

The water will continue to travel up the chalk, carrying the blue and yellow components (if green food color is used). When they get to the top edge, they have nowhere to go. The water, however, will tend to evaporate from the top. Thus the blue and yellow components will recombine and a green color will reappear at the very top, as it did in the filter paper.

Depending on several conditions, the time it takes for the materials to reach the top may vary. If, by the end of the day, the two components have not combined, leave it overnight. Check the system periodically to be certain that there is an adequate amount of water in the container.

2. Use either the filter paper or the chalk technique, or both, to try to separate the components in other food colors, and in inks.

Several possible solutions are listed under Materials and Equipment. Since the components of the listed inks and food colors are soluble in water, the same procedure as used with green and blue food color can be used in their separation. Again, the color separation results can be compared with the color combination results in the mosaics Activity.

Selecting at least one solution (either ink or food color) which has only one colored component will be instructive for the children. They should be helped to see that either such a solution is actually composed of one kind of colored particles or that only one kind is soluble in water.

The comparison of separation effects in food color and inks is interesting. Inks are different, chemically, from food color. Some children may notice that whereas they got opposite effects using food color in filter paper and chalk--that is, the component that moved relatively faster in one medium moved relatively slower in the other--they may get the same effects with inks: the same component will travel at the same relative speed through both media so that the same order of separation will be obtained.

A Sample Activity From
Teacher's Guide for Grade Four

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Activity 1 "Disappearing" Heat Energy Units

Children will re-encounter here certain concepts developed in Minisequence II--that when samples of water are mixed, the volume of the mix is the sum of the volumes of the samples, and the heat energy of the mix is the sum of the heat energies of the samples. With these concepts, they have found that they can successfully predict the temperature of a mix. This can be done because heat energy is neither gained nor lost when water samples are mixed.

In this Activity, however, the children face a dilemma. In one instance some solid water (ice) is substituted for liquid water going into the mix. They discover that the resultant mix seems to have less heat energy than predicted. Some h.e.u. seem to have disappeared. This leads them to speculate that heat energy may have been needed to effect a "change of state"--the change of ice to water.

MATERIALS AND EQUIPMENT:

- 60 polyfoam cups, 6-oz to 8-oz (180-ml to 210-ml)
- 6 polyfoam containers, 3-qt (3-liter), with lids
- 18 unit-measure cups, plastic or waxed paper, 1-oz (30-ml)
- 30 thermometers, e.g., Macalaster No. 2662, -20°C to $+50^{\circ}\text{C}$
- 30 sheets of graph paper, 4 squares/in. (2 squares/cm), or 60 copies of Worksheet II-3
- 90 ice cubes (in two different batches for use on two different days)
- 3 kitchen measuring cups or scoops (optional)
- 30 paper towels
- 30 pencils and/or felt-tip pens

PREPARATION FOR TEACHING:

Clearly label three of the large polyfoam container A and the other three containers B. Ice cubes and water will be placed in

the A containers. There is a limitation as to the maximum (not the minimum) size that the ice cubes should be. Each cube should be no larger than the volume of a 1-oz unit-measure cup. (It need not be cubic in shape.) There are several ways to get small ice cubes. If the ordinary trays are only partly filled with water, the ice cubes will be smaller than usual. The cubes could also be broken into somewhat smaller pieces, or reduced in volume by letting them let down in warm water in one of the containers. They could also be crushed, but this is not necessary. There is no need for the cubes to be the same size. Put about 15 of these ice cubes into each of the three A containers and then add very cold tap water until the container is $\frac{2}{3}$ full. Fill the three B containers $\frac{2}{3}$ full of water at a temperature of 30°C to 35°C . The containers should not be more than $\frac{2}{3}$ full to minimize loss or gain of h.e.u. with the surroundings. If Section 3 is done on a different day, the preparation of these containers will have to be repeated.

Cover all containers and place them in different parts of the room, where they will be easily accessible to the class. Place 3 unit-measure cups near each container and, if available, scoops near the A containers.

ALLOCATION OF TIME:

The children will need about 1-1/2 hours for this Activity.

TEACHING SEQUENCE

1. The Activity can be introduced by asking the children if they remember how to predict the temperature of a water mix formed by combining samples of known temperature and volume. After raising this question, pour 2 1-oz unit measures of water from container A into a polyfoam cup; place 3 measures of water from container B into another polyfoam cup.

- How would you predict what the temperature of the mix would be if sample A and sample B were combined?

COMMENTARY

It has been sometime since they completed Minisequence II. Therefore, a review is recommended in order:

In Minisequence II, the basic concepts developed were:

1. The heat energies in samples of water can be compared by comparing the number of heat energy units (h.e.u.) in each sample.
2. The number of h.e.u. depends on both the volume and temperature of the water; the number can be determined graphically by counting squares of a plot of volume and temperature (or arithmetically by multiplying).

TEACHING SEQUENCE

COMMENTARY

1. When samples of water are mixed, the heat energies of the samples (and the volumes) add together and appear as the sum in the mix. Heat energy is conserved--it is neither lost nor gained--in the process.

To predict the temperature of a water mix:

1. The children measured the temperature and the volume of the water in each sample which was to go into the mix.

2. V-T graphs of each sample were made.

3. Then the h.e.u. in each sample were counted. (Note that this is the area of the V-T graph, which represents the product of V and T.)

4. The volumes of water in the two samples were added to find the volume of the mix.

5. The width of the mix graph was made equal to the sum of the measures in the mix.

6. The h.e.u. in the two samples were added together to find the h.e.u. expected in the mix.

7. On the V-T graph of the mix, they found how high the temperature would have to be to include all of the h.e.u. in the mix. Alternatively, instead of counting the h.e.u. to be expected in the mix, they could place the samples adjacent to each other and even them off to find what the resulting temperature would be.

8. The predicted temperature

TEACHING SEQUENCE

COMMENTARY

2. Distribute 2 polyfoam cups, a thermometer, and a sheet of graph paper to each child or team of children. Ask them to make their cups A and B to correspond to the labeling of the two polyfoam containers.

Have the children take 3 measures of the 10°C to 15°C water from container B and place it into cup B. Next have them put 2 measures of the ice water only from container A into cup A.

After all of the children have obtained their samples of water, they should measure the temperature of the water in each cup and record these on the graph paper, along with the amount of water in each sample. They should then use a pencil to draw a line inside of cup A to mark the top of the water level. This mark represents the height reached by two measures of water and will be used for reference later in the Activity.

Ask them to predict the temperature to be expected when sample A and sample B are mixed.

was then verified by preparing the mix and actually measuring the temperature.

This part of the Activity may be performed by the children individually or in teams of 2 or more. It will probably not take more than one class period. Either graph paper or copies of Worksheet II-3 from the Water-Mix sequence can be used by the children for making their graphs. However, if graph paper is chosen, the back of the paper can be used for the second experiment. Two copies of the Worksheets would be needed for both experiments.

No ice should be taken with the 2 measures of ice-water.

They should use the same thermometer to measure the temperature in each sample. Slight variations in thermometers might cause predicted temperatures of the mix to be off. Be sure the stems are not slipping. If so, some may need a piece of tape to hold the upper part of the stem on to the plastic backing. The temperature of the ice-water in container A will be close to 0° or 1°C. In the cups the temperature of the water may be a bit higher, since the cup itself was at room temperature.

To make this prediction they should prepare a V-T graph for each sample and for the resultant mix. The temperature of

TEACHING SEQUENCE

They should now check their predictions by mixing sample A and sample B, stirring the mix and measuring its temperature. They should find that, in this instance, as in all previous experiences, they could predict the temperature of the mix with confidence.

As a review of the major concepts underlying their ability to predict correctly the temperature of the expected mix, the following questions may be used in discussing their results:

- Were your predictions confirmed by the actual mix? Why do you think this was so?
- In addition to the heat energy units adding up, what other units of the samples were added in the mix?
- How did the temperature of the mix compare with those of the samples?

COMMENTARY

the mix will be determined by how high they would have to go on their V-T graphs to accommodate the h.e.u. of the mix. As they do this, be sure they count the h.e.u. in each sample and then in the mix. The illustration on page 289 shows a typical set of graphs for this experiment.

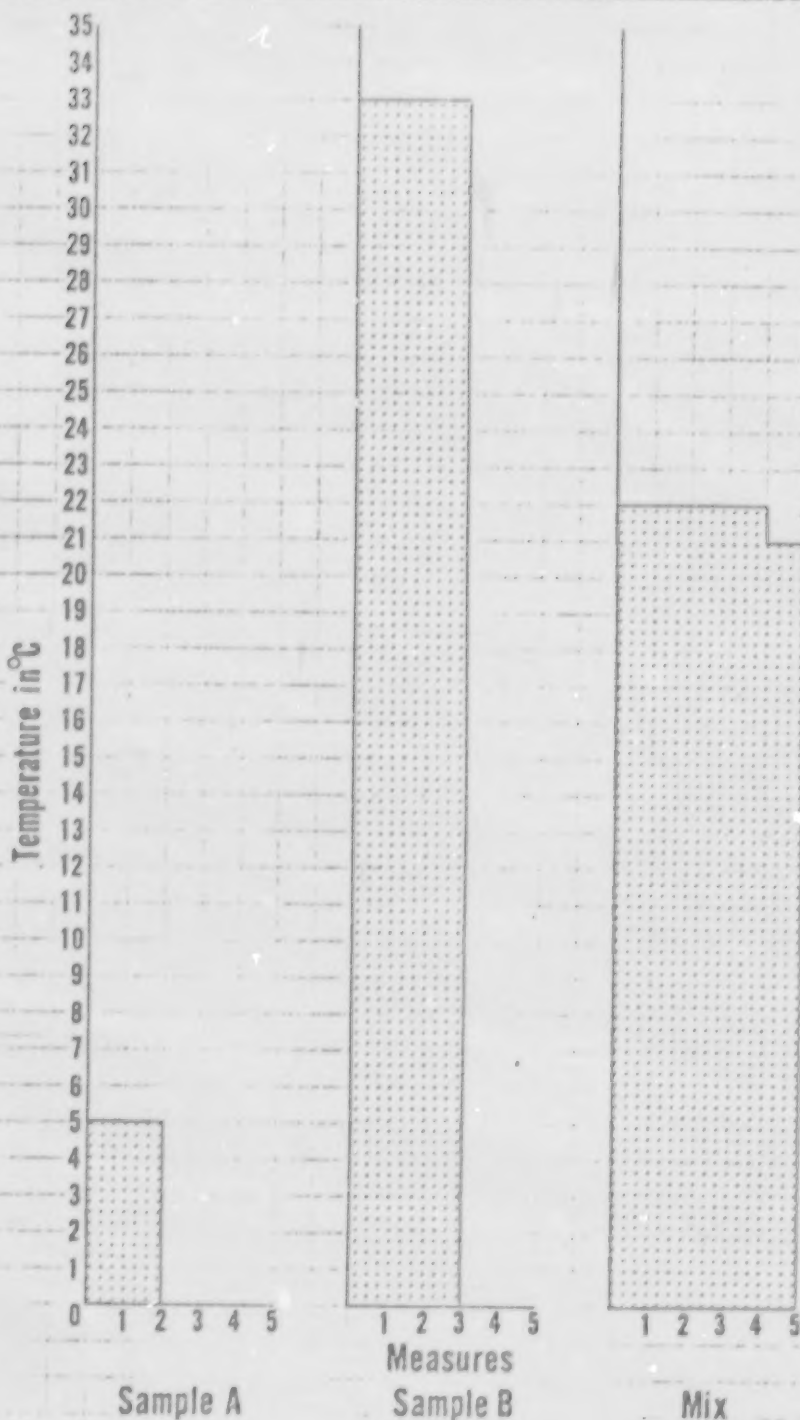
Before checking their predictions, have them make sure the temperature of the samples have not changed appreciably. They should remember that in measuring temperatures of water samples, they should keep the bulb of the thermometer in the water until the column of liquid in the thermometer no longer changes position.

The heat energy units in the mix are the sum of the heat energy units in each sample.

The volumes added up.

As was found in previous water mixing experiments where the temperatures of the samples were unequal, the temperature of the mix was somewhere between the two.

The children should have noted that there was no loss of heat.



Temp. 5°C Temp. 33°C Predicted Temp. 22°C

Volume 2 meas Volume 3 meas Volume 5 meas

h.e.u. 10 h.e.u. 99 h.e.u. 109

TEACHING SEQUENCE

3. Next, suggest that the children try the same experiment using ice in place of some of the water in the cold sample. Ask them to take again 3 measures of water from container B (30°C to 35°C) and put them into cup B. Into cup A they will put 2 measures of ice and water from container A. To do this, they should scoop up as much ice as will fit into a 1 unit-measure cup and pour it into cup A. Then they should use the unit-measure cup to add enough water from the same container (but no more ice) until the level of the liquid comes up to the pencil line they drew after they had poured in 2 unit measures of ice-water alone during their first experiment.

The children can measure the temperature of the sample in each cup and record both the amount and temperature on their graph paper.

COMMENTARY

energy in the mix. A count of h.e.u. squares should confirm this. Those children adept at multiplication will be able to predict the temperature of the mix by product calculation. Even so, their attention should be drawn to the area on the graph--the count of the squares--being equal to the sum of the areas for samples A and B. Attention to the graph areas should help to reinforce the concept of conservation.

The exact amount of ice is unimportant as long as they take about one unit-measure.

These records should be labeled-- for instance "Experiment 2"--since the temperatures may be very similar to that measured for the samples in the first experiment. Cup A has some ice in it; therefore its temperature may be a bit lower than the ice-water alone. It may be as low as 1°C or even slightly lower. (The only way

TEACHING SEQUENCE

Now ask them to draw a graph representing the temperature and the volume of these new samples, and to predict the temperature for the new mix.

Next, they should verify their predictions by mixing samples A and B. Have them do this by pouring sample B (the warmer one) into A. They should continue to stir the mix with their thermometers until all of the ice is melted. They will find that the final temperature of the mix will be considerably lower than that predicted.

COMMENTARY

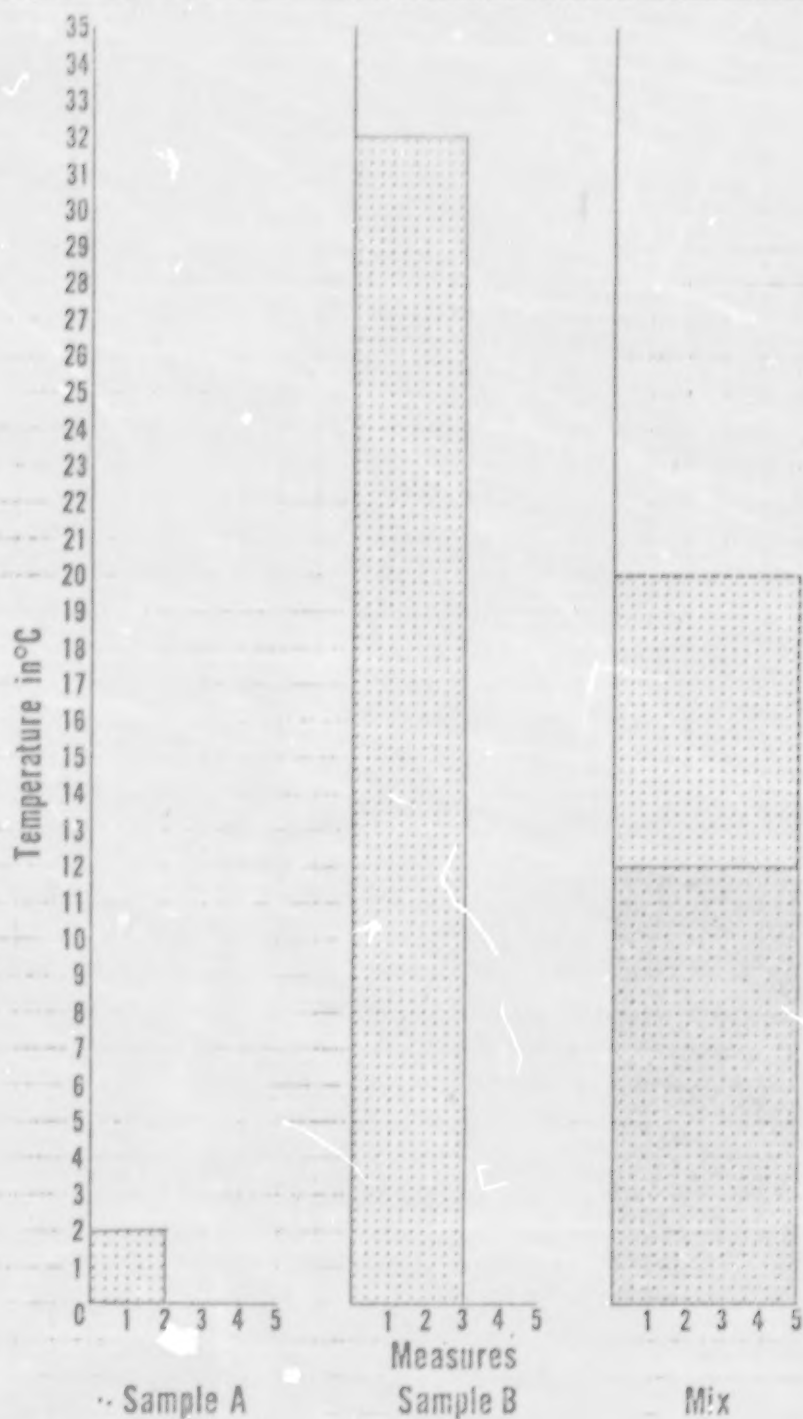
to obtain a perfect 0°C reading is to have finely crushed ice mixed with the water. Such a temperature is not necessary for this experiment.)

If the ice plus water sample registers close to 0°C , which it may, some children may wonder how to graph this. Keep in mind that the h.e.u. has been defined as the product of the Celsius temperature and the unit-measures (here they are 1-oz unit-measures). Since on this scale 0°C occurs where ice melts, a sample of water at this temperature would seem to contain no h.e.u.

This does not mean that the sample contains no heat energy. If one used a different scale, such as Fahrenheit, the melting point of the ice would be 32°F , and the h.e.u. would then differ. But the comparison between systems would be valid.

No problem should occur if the temperature is 1°C --there would be 2 h.e.u. contributed by this sample to the mix. If the temperature is 0.5°C , the children can estimate that about 1 h.e.u. is added.

The children will be confronted with a very puzzling situation. Unlike the previous mix, the temperature of the mix will fall below the predicted temperature. It will probably be several minutes before the temperature of the mix stops dropping. This is the first time that the children will have been faced with a situation in which their predicted temperature was much different from that obtained by experimental

Temp. 2 $^{\circ}\text{C}$ Temp. 32 $^{\circ}\text{C}$ Predicted Temp. 20 $^{\circ}\text{C}$ actual
temp 12 $^{\circ}\text{C}$ Volume 2 meas.Volume 3 meas.Volume 5 meas.h.c.u. 4h.c.u. 96h.c.u. ~~120~~ 60

TEACHING SEQUENCE

Have them prepare a V-T graph to calculate the number of h.e.u. in the mix as it was actually produced.

Ask them to compare this predicted V-T graph with the V-T graph they actually obtained.

- How many heat energy units should have been in the second mix? How many did you actually find?

Without pushing them for answers, encourage the children to attempt to explain what happened to the "lost" h.e.u.

COMMENTARY

test in making a mix.

Alternatively, they could mark the area on the V-T graph representing their prediction that encloses the number of h.e.u. actually in the mix. (See the illustration on page 292.)

The graph for the experimental mix will show much less heat energy in it as calculated by the product of V and T.

The first reactions are likely to be ones of puzzlement and dissatisfaction with the graphing results. Several h.e.u. seem to be missing. Some children may think their thermometers are broken. If they feel there were errors in the way they prepared the mix or the graphs, they should be encouraged to investigate the possible sources of error and even to repeat the experiment. Some children may want to investigate the order of mixing.

The discovery of the missing heat energy units is a critical point of the sequence. In this activity, children are confronted for the first time with the possibility that heat energy units apparently are not conserved.

If some suggest that the temperature went "way down" because the ice was so cold, have them hold the bulb of the thermometer against an ice cube. They will see that the temperature is not below 0°C --in fact, since the entire bulb is not surrounded by ice, it might register slightly above 0°C . Therefore the ice was not much colder than the ice-water in

TEACHING SEQUENCE

- What was the basic difference between the two mixes?
- What do you think caused the ice to melt?
- How much heat energy was needed to melt the ice in the second mix?
- What happened to the heat energy in the first mix as compared to the second?

COMMENTARY

the first mix where they were able to predict the mix temperature successfully. Also, an ice cube taken from a freezer, without surrounding water, will be at a temperature initially below 0°C. In this Activity, however, the ice has been floating in water and will have "warmed up" to 0°C, its melting temperature.

Because of inefficient mixing, as the children have found, the actual temperature may be a bit above 0°C.

The children should see that the only difference was that the second mix contained ice as well as water.

The children should remember from earlier experiences that the addition of heat energy is necessary to cause ice to melt. Try to elicit the suggestion that heat energy units may have been needed to do the job of melting the solid water into liquid water.

The children can answer this question by consulting their graphs.

At this point it is important to emphasize the role played by heat energy in each of the two mixing events. Help the children to understand that in the first instance two liquids were mixed and the heat energies from both samples were simply distributed throughout the mix. In the second instance, however, a liquid and a solid were mixed and a change occurred in the state of the solid. They should be able to speculate that some of the heat

TEACHING SEQUENCE

COMMENTARY

energy of the system was used in melting the ice.

Ask them to save the two graphs for reference in Activity 2.

This Activity usually generates lively interest for the children. Some may want to repeat the mixes using different ratios of water, ice-water and ice to see what the final temperatures may be. They will find that in all instances where the ice is put into the mix, h.e.u. will be "lost" from the graph of the final mix. The number lost will depend on how much ice was added.

A Sample Activity From
Teacher's Guide For Grade Five

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Activity 4 When Do Seeds Germinate?

In this Activity the children are directed to the study of variable events in populations of living things. Earlier in the COPEs curriculum children were introduced to the concept of expected variability in nature. In the present Activity this concept is reinforced; the children find variations in the time it takes a kind of seed of a specific population to germinate. The germination times are visually portrayed in the form of histograms whose characteristics are found to be similar for all samples from the same population of seeds. The range, the peak value, and the average time for germination are properties of the population. Thus, two kinds of seeds (different populations) with different peak germination times can be distinguished from one another by the shape of the histogram representing the frequency distribution of germination times. This is discovered when some children investigate an apparently homogeneous population of seeds and discover that the resulting histogram has two peak germination times. They then infer that their sample probably consists of a combination of two different kinds of seeds. Thus the shape of a histogram can provide clues as to whether a given sample is made up of cases from a single or from several populations.

MATERIALS AND EQUIPMENT:

You will need:

- 3 packets* each of seeds such as radish or turnip and popcorn or dill, lettuce, etc.
- 2 packets* of Forget-me-not seeds (*Myosotis*, not *Cynoglossum*)
- 1 packet* of *Celosia* seeds
- 3 or 4 plastic spoons (1 for each bag of seeds)
- 3 or 4 plastic sandwich bags
- containers of water

In addition, for each pair of children, you will need:

- 2 plastic sandwich bags or plastic wrap
- 2 small dishes, 3-in. to 5-in. (7.6 to 12.5-cm) diameter and 1/4-in. to 1/2 in. (0.8 cm to 1.3-cm) deep

- 10 paper towels
- 1 medicine dropper
- 1 pair of tweezers (optional)
- 1 copy of Worksheet V-4
- 2 sheets of graph paper, 10 sq/in.

*Note that seed packets contain widely different numbers of seeds. There should be enough so that each team of 2 children can take 100 seeds from one of the bags described under Preparation for Teaching.

PREPARATION FOR TEACHING:

Mix the packet of *Celosia* seeds with the two packets of Forget-me-not seeds. Put this mixture in a plastic bag and label it with a letter such as "C." There are two varieties of seeds commonly sold as Forget-me-not. You must obtain the one marked "*Myosotis*," not "*Cynoglossum*." The first is also known as scorpion grass, the latter as hound's tongue. It is *Myosotis* which will have enough of a difference in peak of germination times, compared with *Celosia*, so that a bimodal histogram will be obtained. The Forget-me-nots are only about 50% viable and therefore 2 packets of Forget-me-nots are needed to 1 packet of *Celosia* seeds.

Transfer the seeds from the other packets to separate plastic bags. Label these bags and the corresponding packets with other letters so that you can identify the seeds later. It would be best to include both a fast and a slow germinating seed. Radish and turnips are fast germinating; dill and popcorn are slower germinating seeds. If you are unsure of the germination time for the seeds you have, set up a sample of the seeds a week beforehand, just as the children will, and check the germination times yourself. Thus, what you should have when you have finished preparing the bags are:

1. A bag containing 3 packets of, say, radish seeds. This bag might be labeled "A."
2. A bag containing 3 packets of, say, popcorn seeds, labeled "B."
3. A bag containing 2 packets of Forget-me-nots and 1 packet of *Celosia*, labeled "C." Mix the seeds thoroughly. The mixture will appear homogeneous because these seeds are very similar in appearance.
4. A bag containing 3 packets of, say, lettuce seeds, labeled "D."

There should be about the same number of seeds in each bag. Place each bag of seeds in a different location to avoid getting them confused and provide spoons and small pieces of paper so that the teams can take their samples.

Put out the supplies of paper towels, dishes, and plastic bags where the teams of children can help themselves. Fill a few containers with water, from which the children can dampen the paper towels once they are placed in the dishes. Medicine droppers are convenient to use for this purpose.

ALLOCATION OF TIME:

About 2 hours, in all, will be needed over a period of a week to complete the Activity.

If the seeds are started Monday morning, peaks in germination will be observed from the first day after being set up (radish) to the fourth day (popcorn or dill) but the decrease on Saturday morning will not be observed. Therefore, the activity should be continued at home.

TEACHING SEQUENCE	COMMENTARY
1. Show the children the bags of seeds. Ask what they are and then what they do.	Many children will surely recognize that the small objects in the bags are seeds and are sure to suggest that they will grow into plants if they are placed in the ground.
• Do you think they will grow into different plants?	Since the seeds are of different shapes, etc., it is more than likely that they will. (See Topic I, Activity 1, of Grade 2.)
• Will all the seeds sprout--that is, germinate?	Probably not--only the living seeds will sprout, as the children found in Grade 1 (Topic I, Activity 7).
• Do you think there will be different germination times for the different seeds? For the seeds in the same group?	Encourage discussion on this point by the children. In Grade 1, Topic IV, Activity 4, children investigated germination times and found some variability within one type of seed and a good deal among different kinds of seeds. Now they will

TEACHING SEQUENCE

Refer to the groups of seeds as samples from populations of particular seeds and suggest that, using such samples, the children investigate the property of germination time for these populations.

- In setting up your experiments, would you want to observe the time it takes for one seed to germinate?--two seeds?

Larger numbers of seeds will be needed. The children can work in teams of two with each team taking a sample of 100 seeds from one of the larger samples of seed populations you have made available to them.

If necessary, remind the children that the seeds can be made to start growing if they are placed on top of moist paper towels. Show them how to do this: Fold a paper towel to fit the bottom of a dish. There should be about 15 to 20 layers. Moisten the towel, put some seeds on it, and place the dish in a plastic sandwich bag to keep the towel from drying out. There should be an air space between the seeds and the plastic.



COMMENTARY

pursue this in greater depth.

By this time, children should be reluctant to base inferences about a population on information derived from only a few members.

Plastic wrap may substitute for the plastic sandwich bags. The bags need not be completely closed.

TEACHING SEQUENCE

Now point out to the children the supplies of paper towels, dishes, water, and plastic bags. Have each team select the particular seed it will investigate. After they prepare their dish and have the towel moistened with water, they should get a supply of 100 of the seeds.

Provide each team with a copy of Worksheet V-4 to be used to record the data. Each team should make a record of the bag from which they took their seeds and of the time (date and hour) when they set up their germinator. The children can also record the physical properties of the seeds they selected, such as comparative size, color, shape, etc. This can be noted on the Worksheet under "Comments." They should then set the germinating dishes aside in the classroom.

2. As soon as some seeds show signs of germination, discuss this with the children. As in Grade 1, a criterion for germination will have to be established. The seed will give evidence of starting to grow--

COMMENTARY

If you wish, this part of the Activity can be conducted by small groups of children working on their own at various times. Be sure that at least a few teams select seeds from every bag so that there will be some data on each one.

They can use the spoons and small pieces of paper to bring the seeds over to a work area.

Since direct sunlight is not conducive to seed growth, the children should keep their dishes away from the windows. On the Worksheet, suggest that they include information as to where the germinator was kept. Subsequently, interested children may wish to pursue the effect of varying amounts of light (even darkness) and repeat the investigation under different conditions.

Some kinds of seeds, such as radish, should exhibit some germinations within one day.

Number of seeds _____ taken from bag lettered _____

DAY	NUMBER OF NEW GERMINATIONS	COMMENTS

TRANSCRIPTION OF COMMENTS

1. The first comment is that the sequence is very clear and easy to follow.

2. The second comment is that the sequence is very clear and easy to follow.

3. The third comment is that the sequence is very clear and easy to follow.

4. The fourth comment is that the sequence is very clear and easy to follow.

COMMENTARY

1. The first comment is that the sequence is very clear and easy to follow.

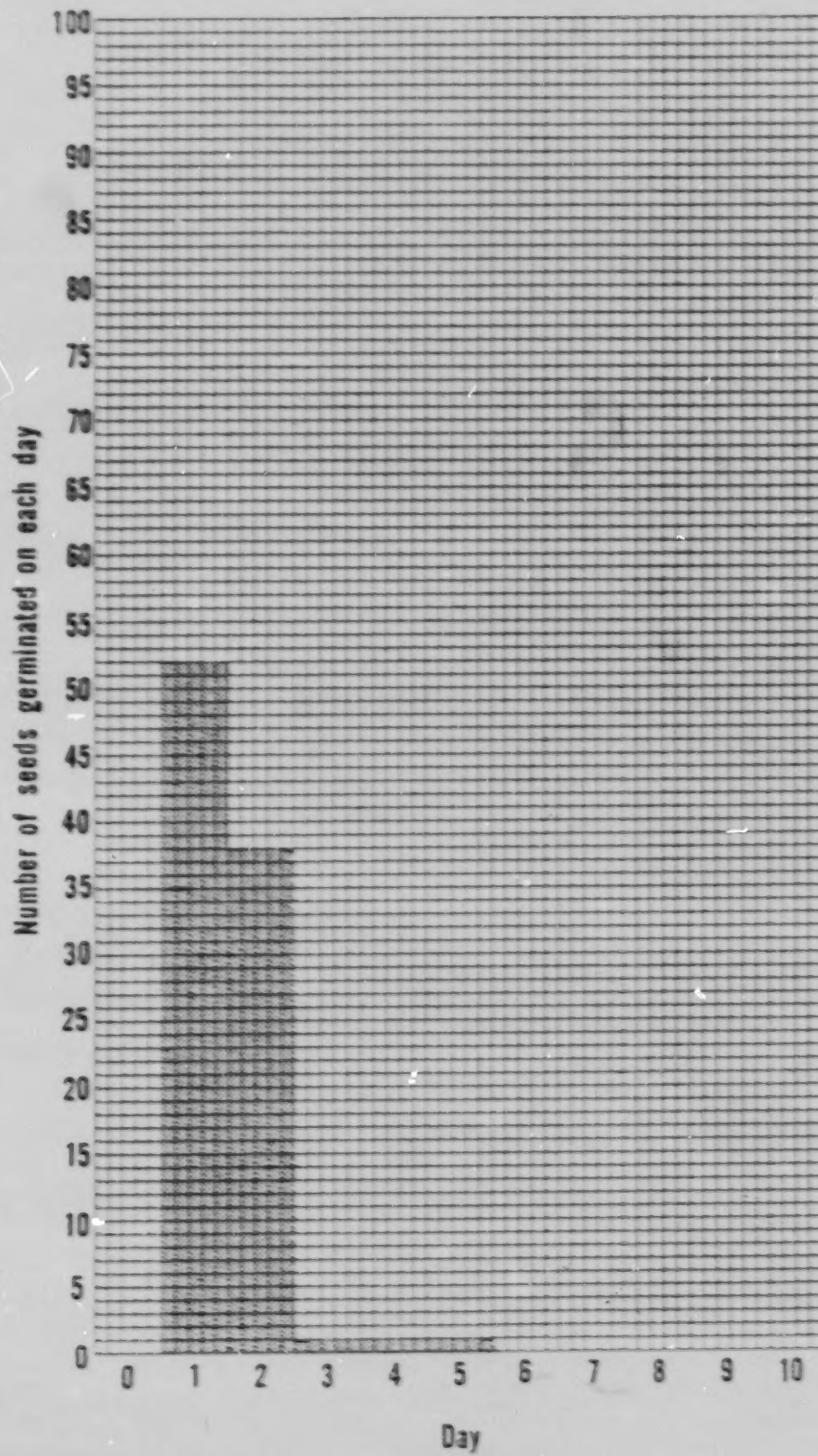
2. The second comment is that the sequence is very clear and easy to follow.

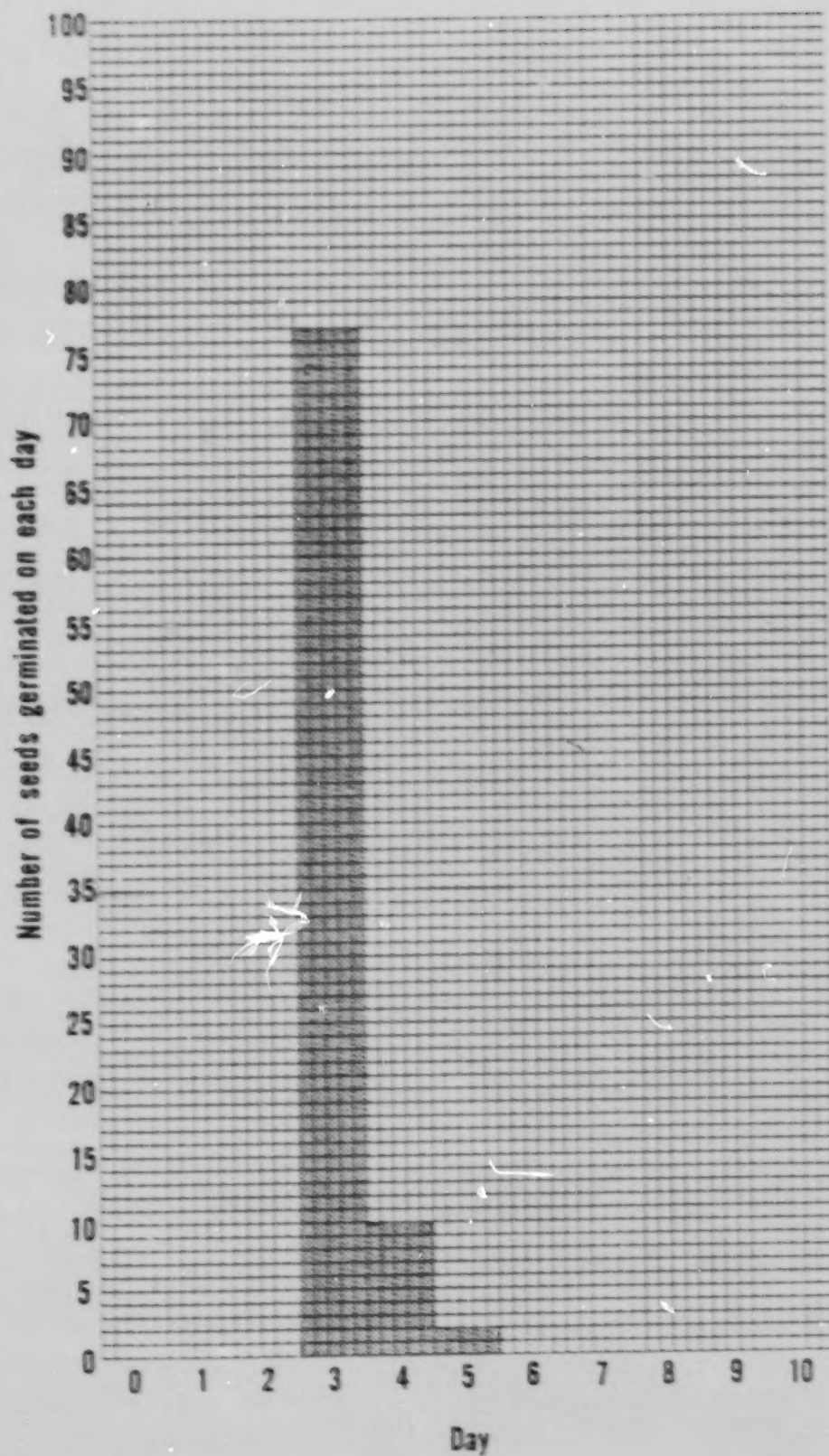
3. The third comment is that the sequence is very clear and easy to follow.

4. The fourth comment is that the sequence is very clear and easy to follow.

Number of seeds 100 taken from bag lettered A

DAY	NUMBER OF NEW GERMINATIONS	COMMENTS
9/11 0	0	START
1	52	
2	38	
3	1	
4	1	
5	1	
6	STOP	7 DID NOT GERMINATE





TEACHING SEQUENCE

COMMENTARY

- If you took another sample from the same population, what would you predict for the peak germination time?

Choose some of the histograms from different teams to show to the class.

- How do the histograms for the same kind of seed compare generally?
- How do the histograms of different seeds compare?

Have the children report on the range in germination times they observed. Did seeds from the same population behave similarly?

- What is the average time of germination for each sample of seeds?
- Suppose you had taken only a few seeds, 5 for instance, would you have confidence

The teams which investigated the apparently homogeneous "population" in Bag C may or may not raise questions, at this point, about the lack of a single peak on their graphs. If they do, accept their questions, admit that their observations are puzzling, but provide no explanation.

They should expect the peak to occur at the same number of days from the start--if all conditions are the same.

Do not pick the graphs from the teams that had the mixture of Celosia and Forget-me-not seeds, i.e., the graphs with two peaks.

They should be similar but generally not identical.

They may be very different, not only as to the day of peak germination, but also as to the value at the peak and to the range of days for germination. All these properties can be discussed in connection with the histograms prepared by the children.

Since the range in many instances is short, the average will probably be near the highest point on the frequency distribution portrayed in the histogram.

Some seeds did not germinate at all and some took longer times than others. The five selected

TEACHING SEQUENCE

COMMENTARY

By now the children should see that in studying populations they must investigate as large a sample as is practicable, since they must expect some variations in results. Ask them if it would be acceptable to combine sets of data, as they have done in the previous Activities, to increase sample size. Perhaps they could then make even more confident predictions about germination time.

- But what about combining the data from different populations? Would useful information be obtained?

Exhibit two histograms of seeds with very different peak germination times, such as radish or turnip and dill or popcorn. Combine the data and make a histogram on the chalkboard or have the children combine them and plot the histogram on a fresh sheet of graph paper.

The children should see that such a combination gives a histogram with two peaks. An average germination time would mean little for such data since there would actually be two average germination times, one for each type of seed.

might have included these seeds. Thus they might have concluded, erroneously, either that the seeds cannot germinate at all or that they take a very long time to germinate.

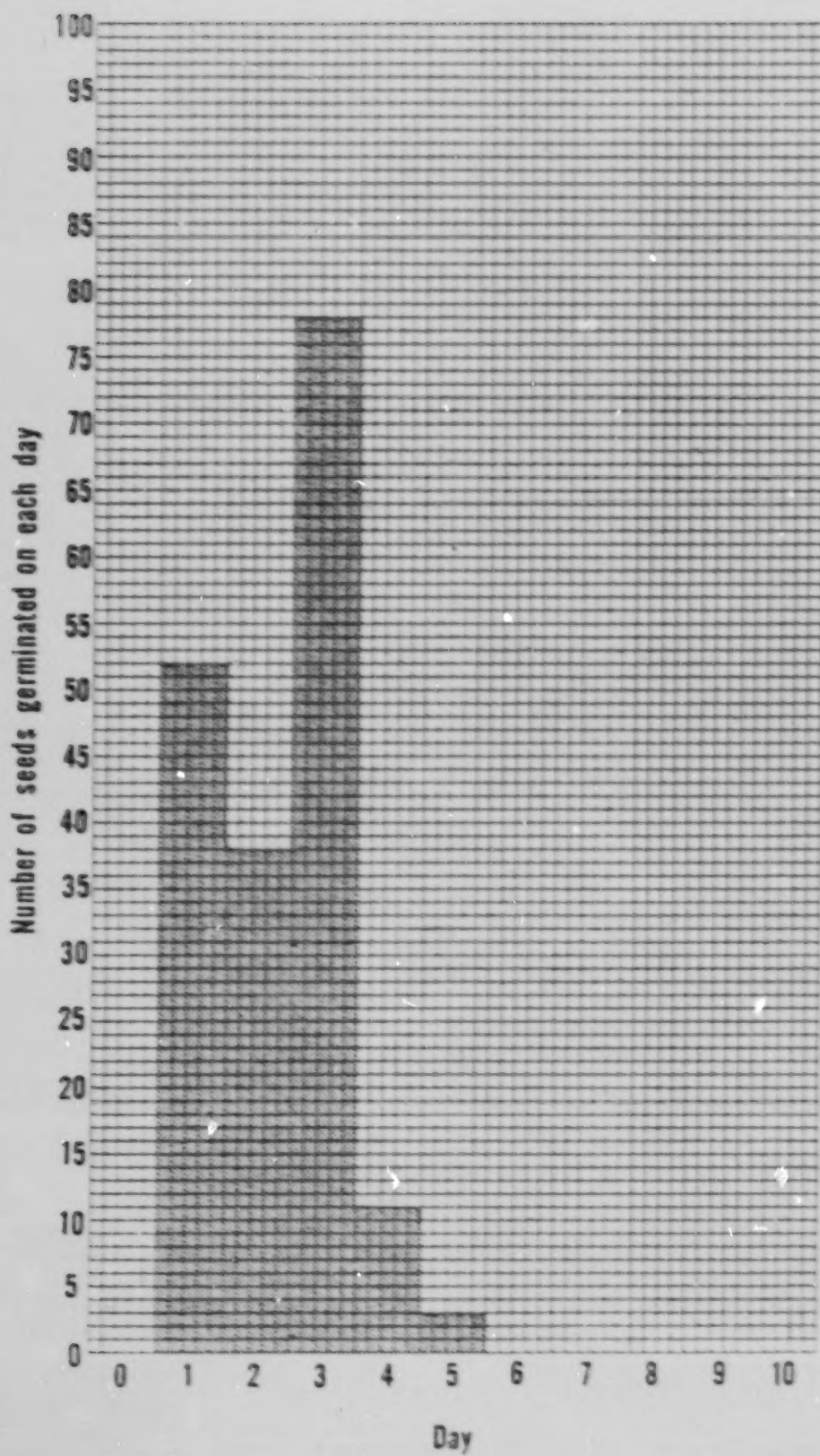
Discussion should bring out that it would be acceptable to combine sets of data from teams who used the same kind of seeds-- that is, seeds from the same bag.

Let the children discuss this problem. After they speculate about it, if a child has not already suggested it, combine some typical data.

A combined histogram for radish and popcorn seeds is shown on page 317.

Such a histogram is referred to as bimodal.

Similarly, the range of germination times for a mixture has little meaning because there are 2 different ranges, one for each population. Thus, when



TEACHING SEQUENCE

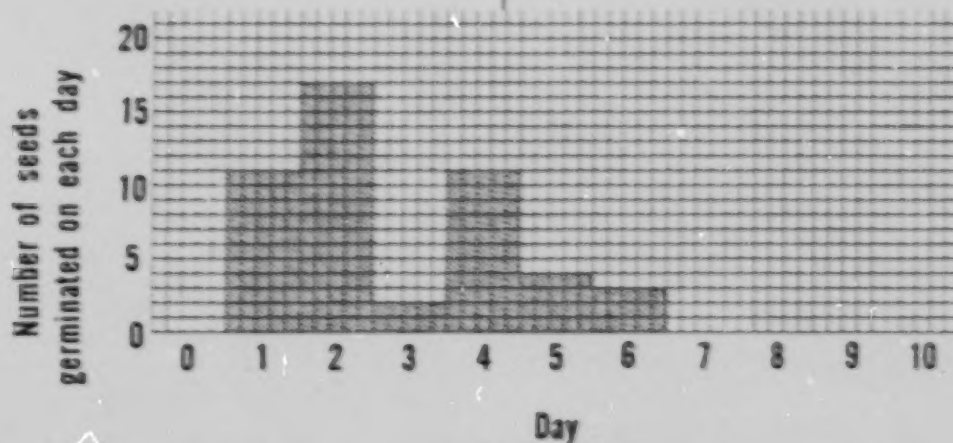
As the children discuss the histograms, ask for many populations are represented in it. Discussion should bring out the idea that the histograms with one peak represent data on single populations of seeds—radish seeds or dill seeds or turnip seeds, etc.—but the combined histogram exhibiting two peaks represents two populations of seeds, each with its own peak germination time.

4. At some point, those children who investigated the mixed Celosia and forget-me-not seeds should begin to raise pertinent questions about their own histograms. Ask them to share their results with the group.

COMMENTARY

Trying to get a better estimate of the average or range of a population, it is important to be certain you are dealing with a single population. Each population has its own average and range. This is really the meaning of the term "population" as used by scientists.

A histogram of the data collected on this mixture is illustrated below. Display such graphs for the entire group to observe.



- What do you notice about the histograms of germination times for the seeds in Bag C?
- Why do you think these histograms have two peaks?

The histograms will be bimodal, just like those which they just constructed (although the two peaks will not occur on the same days or have the same values).

The children should come up with the idea that there were

TEACHING SEQUENCE

- How could you verify the hypothesis that there are really two kinds of seeds in Bag C?
- Suppose you were investigating a group of objects that you suspected might really be two different populations. How would you go about finding out?

COMMENTARY

two different kinds of seeds in Bag C, despite their similar appearance. Of course, there is some overlap on the histogram. Although the average time for the germination of population 1 is 2 days and the average time for the germination of population 2 is 4 days, a few seeds from population 1 must have germinated by the 4th day and a few from population 2 must have germinated on the 2nd day.

They could verify it by letting the tiny seedlings develop far enough to see the differences in the plants which form. Encourage the children to follow through with such a procedure. At that point, you might identify the seeds that were in the mixture. (See Extended Experiences for another verification procedure.)

Make a histogram of data on the group and see if it contained two peaks. This illustrates the use of a statistical procedure to find out something about a set of data. When a histogram for a certain measurement on a population shows two or more peaks, a factor can usually be found which accounts for the shape. Here the factor was that two different kinds of seeds were mixed. As another example, a histogram of the height of adult Americans would also show two peaks. The factor underlying this is the differences in height of men and women. Women, on the average, tend to be shorter than men.

The children may find that certain varieties of lettuce seeds show 2 peaks. Is this a

TEACHING SEQUENCE

COMMENTARY

All these observations point up the use of statistical data in studying samples from apparently homogeneous populations. Although individual deviations occur (very short or long germinations), the peak or most probable time for germination can be confidently used for prediction with respect to the total population even when the total cannot be tested.

Observations on lettuce or does the package contain too varieties? Perhaps letting it grow to maturity will answer the question, but the shape of the histogram will raise the question.

Of course, apparent homogeneity does not guarantee that the seeds have the same size, shape, etc. That populations deviate with respect to germination time is a reason that the latter is usually considered a more important property of the seeds than their outward appearance.

EXTENDED EXPERIENCES:

1. Children can investigate the various factors which may affect the range and average time for germination of different seeds. They can set up samples from a packet of seeds under varying light conditions, (light versus dark); or the effects of different colors of light (using colored transparent plastic or cellophanes), the effect of watering, etc. This type of investigation is highly suitable to individual investigations, either at school or at home. In all instances, they should take their data on a large enough sample so as to make their results statistically sound.

2. Those children who had germinated the mixed populations of seeds may want to get the data on the individual populations and then combine the data on a histogram to see if it looks like the one they obtained on the mixture. If it does, this might also verify that it was a mixture.

3. Many commercial seeds are really mixtures, such as some grass seeds. Children might take germination-time data on samples to see if a histogram will confirm this. Sometimes, overlap of the bars obscures the separate peaks, however.

Selected Assessment Materials From
The Teacher's Guide for Grade Three

Minisequence III Assessments

Screening Assessments

The following concepts are tested in this assessment:

1. An average is a number representative of a set of measurements. One average is obtained by an evening-off process from the highest measurement to the lowest, giving an evening-off number near the middle of the set.
2. The average and range of values in a sample are useful in estimating those characteristics of the population sampled.
3. Averages of large samples are better predictors of the average of a population than the averages of small samples because averages of large samples show less variation than the averages of small samples.
4. The count of objects or units of measure can be represented, in a one-to-one correspondence, by unit markers or squares on a graph. Averages obtained by evening off markers or squares apply to the initial measurements.

Distribute the 3 assessment pages to the children. Have them write their names in the appropriate place on the first page. There is only one part, with 9 items, which should take about 15 minutes to complete.

PAGES A, B, and C

Remind the children about the Activities where they found averages by evening off a distribution. Now they are going to be asked some questions about averages and they will determine some averages. (Allow one minute for the children to respond to each item.)

Page A

LOOK AT THE PAGE WITH THE APPLE.

Page A, top: SOME CHILDREN IN A CLASS COUNTED HOW MANY PENCILS EACH CHILD HAD. THE BAR GRAPH AT THE TOP OF THE PAGE SHOWS HOW MANY PENCILS EACH OF FIVE CHILDREN HAD. BELOW THE BAR GRAPH ARE SOME NUMBERS. ONE OF THEM SHOWS WHAT THE AVERAGE NUMBER OF PENCILS IS. DRAW A CIRCLE AROUND IT.

Page A, middle: THE BAR GRAPH IN THE MIDDLE SHOWS HOW OLD EACH OF SIX CHILDREN IN A CLASS WAS ON HIS OR HER LAST BIRTHDAY. DETERMINE THEIR AVERAGE AGE AT THEIR LAST BIRTHDAY AND WRITE THE NUMBER ON THE DASHED LINE.

Page A, bottom: THE NAMES OF FOUR CHILDREN ARE SHOWN AT THE BOTTOM OF THE PAGE. THE NUMBER OF BROTHERS THAT EACH CHILD HAS IS WRITTEN BELOW EACH NAME. MAKE A BAR GRAPH BY SHADING THE SQUARES TO REPRESENT HOW MANY BROTHERS EACH CHILD HAS. (Pause for about 90 seconds.) NOW DETERMINE THE AVERAGE NUMBER OF BROTHERS FOR THE GROUP AND WRITE IT ON THE DASHED LINE.

Page B

TURN TO THE PAGE WITH THE BAT.

Page B, top: THE CHILDREN IN A CLASS WERE GOING TO SHARE SOME MARBLES WHICH WERE IN A BAG. EACH CHILD PUT HIS HAND IN THE BAG AND TOOK OUT SOME MARBLES. THE NUMBER OF MARBLES THAT EACH CHILD TOOK OUT IS SHOWN AT THE TOP OF THE PAGE. THE CHILDREN ARE GOING TO SHARE THE MARBLES EQUALLY. DRAW A CIRCLE AROUND THE NAMES OF THE CHILDREN WHO WILL GET MORE MARBLES THAN THEY NOW HAVE. DRAW AN X ON THE NAMES OF THE CHILDREN WHO WILL GET LESS MARBLES THAN THEY HAVE NOW.

Page B, middle: FIVE CHILDREN IN A CLASS HAVE COMIC BOOKS. THE NUMBER OF BOOKS EACH CHILD HAS IS SHOWN IN THE MIDDLE OF THE PAGE. THE CHILDREN ARE GOING TO SHARE THE COMIC BOOKS EQUALLY. DRAW A CIRCLE AROUND THE NUMBER WHICH SHOWS HOW MANY EACH WILL PROBABLY GET.

Page B, bottom: FIVE CHILDREN CLEANED OUT THE DESKS IN THEIR CLASSROOM. THE NUMBER OF DESKS EACH CHILD CLEANED IS SHOWN UNDER THEIR NAMES. THEY DECIDED THAT THE NEXT TIME THEY WOULD EACH CLEAN OUT THE SAME NUMBER OF DESKS. LOOK AT THE THREE NUMBERS AT THE BOTTOM. DRAW A CIRCLE AROUND THE ONE WHICH SHOWS HOW MANY DESKS EACH CHILD WILL PROBABLY CLEAN OUT NEXT TIME.

Page C

TURN TO THE PAGE WITH THE CUP.

MINISEQUENCE III Assessments

Page C, top: DARRELL AND JANICE WANTED TO ESTIMATE THE AVERAGE AGE OF ALL THE CHILDREN IN THEIR SCHOOL. DARRELL ASKED THREE CHILDREN THEIR AGES AND JANICE ASKED SEVEN OTHER CHILDREN THEIR AGES. IN THE TOP ROW, DRAW AN X IN THE BOX UNDER THE NAME OF THE CHILD WHOSE ESTIMATE WOULD BE BEST. IF YOU THINK BOTH ESTIMATES WOULD BE EQUALLY GOOD, DRAW AN X IN BOTH BOXES.

Page C, middle: A GROUP OF CHILDREN HAD SOME JELLY BEANS. THE MOST ANY CHILD HAD WAS SEVEN BEANS AND THE LEAST ANY CHILD HAD WAS ONE BEAN, AS SHOWN IN THE TWO FILLED-IN BARS IN THE MIDDLE OF THE PAGE. THE CHILDREN SHARED THE BEANS FAIRLY. HOW MANY WOULD YOU PREDICT EACH CHILD HAD AFTER SHARING? PUT X'S IN THE SQUARES IN THE EMPTY BAR TO SHOW THE NUMBER OF BEANS.

Page C, bottom: ARNOLD AND DOROTHY WANTED TO KNOW WHICH THE THIRTY CHILDREN IN THEIR CLASS LIKE BETTER, TELEVISION OR RADIO. ARNOLD ASKED TWELVE CHILDREN AND DOROTHY ASKED THREE CHILDREN. MOST OF THE CHILDREN ARNOLD ASKED LIKE TELEVISION AND MOST OF THE CHILDREN DOROTHY ASKED LIKE RADIO. IF YOU THINK MOST CHILDREN IN THE CLASS LIKE TELEVISION BETTER, DRAW AN X IN THE BOX UNDER THE WORD TELEVISION; IF YOU THINK MOST CHILDREN LIKE RADIO BETTER, DRAW AN X IN THE BOX UNDER THE WORD RADIO.

name

6 pencils
5 pencils
4 pencils
3 pencils
2 pencils
1 pencil

Morris Joe Phil Lois Darrell

2

3

4

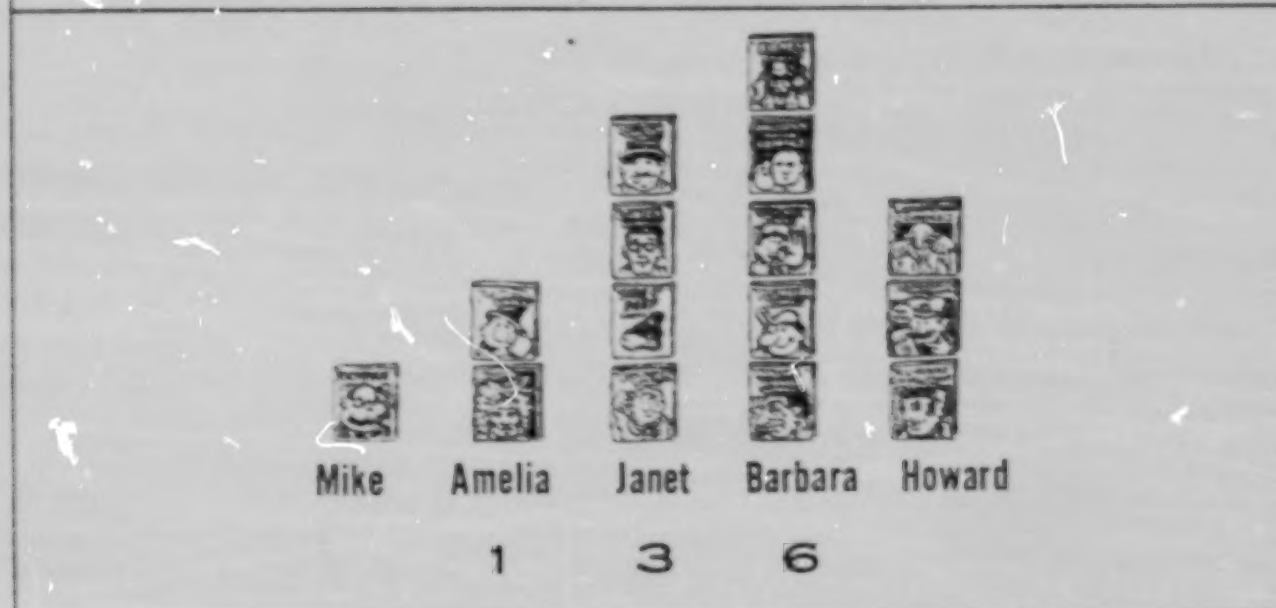
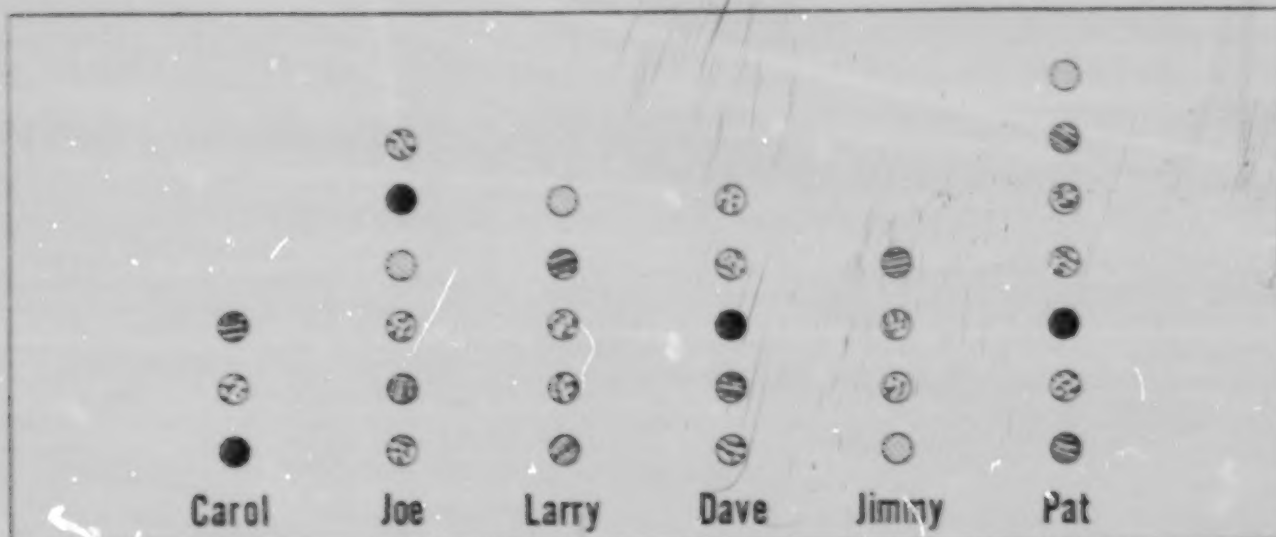
9 years
8 years
7 years
6 years
5 years
4 years
3 years
2 years
1 year old

Arnold Janice Dean Dorothy Carol Kathy

Phil
2
Dean
3
Jan
1
Arnold
2

5 brothers
4 brothers
3 brothers
2 brothers
1 brother

Phil Dean Jan Arnold



Muriel	Mary	Arnold	Al	Sophie
4	6	5	4	6
	5	2	7	



Darrell

☐

Janice

☐

x	x	x	x	x	x	x		
---	---	---	---	---	---	---	--	--

x								
---	--	--	--	--	--	--	--	--

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television

☐

radio

☐

Selected Assessment Materials from
the Teacher's Guide for Grade Four

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E-52

Minisequence II: Assessments

Screening Assessments

The concepts being tested in this Minisequence are:

- a. The heat (thermal) energy of a liquid depends upon (is a function of) both the temperature and the quantity of the liquid.
- b. Heat energy is conserved when liquids are combined.

Part 1 tests the first concept and Parts 2, 3, 4, 5, and 6 test the second concept.

Distribute the six assessment pages to the children. Have them write their names in the appropriate places. Part 1 (pages A and B) should take about 5 minutes. Part 2 (page C) should take about 7 minutes. Part 3 (Page D) should take about 7 minutes. Parts 4 (Page E), 5 (Page F), and 6 (Page G) should take about 5 minutes each.

PART 1

Pages A and B

Page A, Top (example): AT THE TOP OF THE PAGE ARE TWO CONTAINERS WITH LIQUIDS IN THEM. NOTICE THAT THE AMOUNT OF LIQUID IN EACH CONTAINER IS DIFFERENT. THE NUMBER UNDER EACH CONTAINER TELLS HOW MANY HEAT ENERGY UNITS EACH LIQUID CONTAINS. THREE ICE CUBES ARE ADDED TO EACH CONTAINER. AFTER A FEW MINUTES THERE IS SOME UNMELTED ICE LEFT IN EACH CONTAINER. WHICH CONTAINER HAS MORE ICE MELTED? DRAW AN X ON IT. (YOU SHOULD HAVE DRAWN AN X ON THE CONTAINER AT THE LEFT.) THERE ARE TWO MORE PROBLEMS ON THIS PAGE AND THREE MORE ON THE PAGE WITH A BAT. IN EACH PROBLEM, THREE ICE CUBES HAVE BEEN ADDED TO EACH CONTAINER AND AFTER A FEW MINUTES, THERE IS SOME ICE LEFT IN EACH CONTAINER. DRAW AN X ON THE CONTAINER IN WHICH MORE ICE PROBABLY MELTED. IF YOU THINK THE SAME AMOUNT OF ICE WOULD MELT IN BOTH CONTAINERS, DRAW AN X ON BOTH CONTAINERS.

3. MORRIS HAD COFFEE. DARRELL HAD HALF OF A CUP OF COFFEE AT 80°C. THEY BOTH POURED THEIR COFFEE INTO AN EMPTY POT. CAN YOU PREDICT THE FINAL VOLUME AND TEMPERATURE OF THE MIX?

- ☒ A. YES, THERE IS ENOUGH INFORMATION.
- ☐ B. NO, YOU NEED TO KNOW THE VOLUME OF MORRIS' COFFEE.
- ☐ C. NO, YOU NEED TO KNOW THE TEMPERATURE OF MORRIS' COFFEE.
- ☐ D. NO, YOU NEED TO KNOW THE TEMPERATURE AND VOLUME OF MORRIS' COFFEE.

(Allow 1 minute for the children to respond.)

PART 3

Page D

Ask the children to turn to the page with the Dog.

IF YOU KNOW THE TEMPERATURE AND VOLUME OF TWO SIMILAR LIQUIDS, YOU CAN USUALLY PREDICT THE TEMPERATURE AND VOLUME OF THE MIX. READ THE PROPERTIES OF TWO LIQUIDS AS PRINTED AT THE TOP OF THE PAGE. THREE MEASURES AT 10°C ARE BEING ADDED TO FOUR MEASURES AT 10°C. LOOK BELOW THE PROPERTIES. THERE ARE TWO SETS OF THREE NUMBERS EACH. ONE OF THE THREE NUMBERS IN THE ROW MARKED V SHOWS THE FINAL VOLUME IF YOU MIX THE TWO LIQUIDS. DRAW A CIRCLE AROUND THE CORRECT VOLUME. (Pause 30 seconds.) ONE OF THE NUMBERS IN THE ROW MARKED T SHOWS THE FINAL TEMPERATURE OF THE MIX. DRAW A CIRCLE AROUND THE CORRECT TEMPERATURE. (Pause 30 seconds.) (If the children request it, give them graph paper to work out the answers.)

NOW DO THE SAME FOR THE OTHER TWO PROBLEMS ON THE PAGE. DRAW A CIRCLE AROUND THE NUMBER IN ROW V THAT SHOWS THE FINAL VOLUME FOR THE MIX AND DRAW A CIRCLE AROUND THE NUMBER IN ROW T WHICH SHOWS THE FINAL TEMPERATURE OF THE MIX. (Allow 2 minutes for the children to complete this page.)

PART 4

Page E

Ask the children to turn to the page with the Elephant.

(Wait 1 minute.)

NOW TURN TO THE PAGE WITH A BAT.

PART 2

Page C

Ask the children to turn to the page with the Cup.

Remind them about the Activities they have done in mixing volumes of water and predicting the final temperature and volume.

I AM GOING TO ASK YOU SOME QUESTIONS ABOUT MIXING VOLUMES OF WATER. AFTER EACH QUESTION I WILL READ THE FOUR ANSWERS. YOU SHOULD LOOK AT THE ANSWERS AS I READ THEM TO YOU. AFTER I HAVE READ ALL FOUR ANSWERS, DECIDE WHICH ONE ANSWER IS CORRECT. MARK AN X IN THE BOX NEXT TO THE ONE CORRECT ANSWER. DO NOT MARK AN ANSWER UNTIL I HAVE READ ALL FOUR CHOICES. (At the teacher's option, the questions and choices may be repeated a second time.)

1. ARNOLD HAD HALF OF A GLASS OF WATER AT 10°C . PHIL HAD HALF OF A GLASS OF WATER AT 20°C . IF ARNOLD POURED HIS WATER INTO PHIL'S GLASS, COULD YOU PREDICT THE FINAL TEMPERATURE AND VOLUME OF THE MIX?

- ☐ A. YES, THERE IS ENOUGH INFORMATION.
- ☐ B. NO, BECAUSE YOU NEED TO KNOW THE TEMPERATURE OF ARNOLD'S WATER.
- ☐ C. NO, YOU NEED TO KNOW THE VOLUME OF PHIL'S WATER.
- ☐ D. NO, YOU NEED TO KNOW THE TEMPERATURE AND VOLUME OF ARNOLD'S WATER.

2. LOIS HAD SOME MILK AT 30°C . JAN HAD A QUART UNIT MEASURE OF MILK AT 60°C . THEY MIXED THEIR MILK IN A LARGE CONTAINER. CAN YOU PREDICT THE VOLUME AND TEMPERATURE OF THE MIXED MILK?

- ☐ A. YES, THERE IS ENOUGH INFORMATION.
- ☐ B. NO, YOU NEED TO KNOW THE TEMPERATURE OF JAN'S MILK.
- ☐ C. NO, YOU NEED TO KNOW THE VOLUME OF LOIS' MILK.
- ☐ D. NO, YOU NEED TO KNOW THE TEMPERATURE OF JAN'S MILK AND THE VOLUME OF LOIS' MILK.

AT THE TOP OF THE PAGE ARE THE TEMPERATURE AND VOLUME PROPERTIES OF TWO SAMPLES OF WATER. UNDERNEATH THE PROPERTIES ARE TWO GRAPHS. ONE OF THE GRAPHS REPRESENTS THE TEMPERATURE AND THE VOLUME PROPERTIES OF THE TWO SAMPLES JUST MENTIONED. DRAW AN X ON IT. (Allow 30 seconds.)

NOW DO THE SAME FOR THE OTHER TWO PROBLEMS ON THE PAGE. DRAW AN X ON THE GRAPH WHICH REPRESENTS THE PROPERTIES OF THE TWO SAMPLES ABOVE THE GRAPHS.

PART 5

Page F

Ask the children to turn to the page with the Flower.

AT THE TOP OF THE PAGE ARE THE TEMPERATURE AND VOLUME PROPERTIES OF TWO SAMPLES OF WATER. UNDERNEATH THE PROPERTIES ARE TWO GRAPHS. ONE OF THE GRAPHS REPRESENTS THE TEMPERATURE AND VOLUME OF THE MIXTURE. DRAW AN X ON IT. (Allow 1 minute.)

NOW DO THE SAME FOR THE OTHER TWO PROBLEMS ON THE PAGE. (Allow 2 more minutes.)

PART 6

Page G

Ask the children to turn to the page with the Glass.

AT THE TOP OF THE PAGE IS A GRAPH. IT REPRESENTS TWO SAMPLES OF WATER. THE RIGHT SIDE OF THE GRAPH IS SHADED TO SHOW HOW THE MIXTURE OF THE TWO SAMPLES WOULD LOOK. THERE ARE TWO OTHER GRAPHS ON THIS PAGE. SHADE IN THE RIGHT SIDE OF THE GRAPH TO SHOW HOW THE MIXTURE OF THE TWO SAMPLES WOULD LOOK. (Allow 3 minutes for the children to complete this page.)

Name: _____



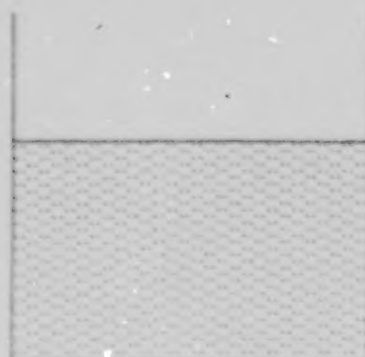
10 h.e.u.



5 h.e.u.



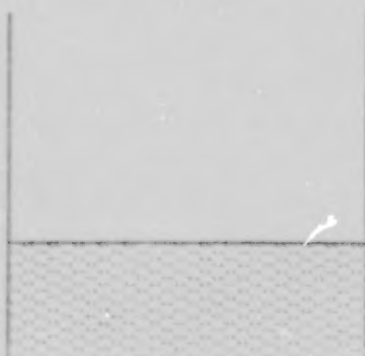
15 h.e.u.



30 h.e.u.



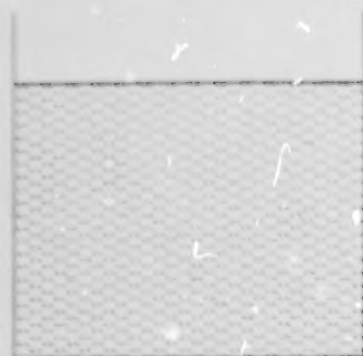
5 h.e.u.



5 h.e.u.



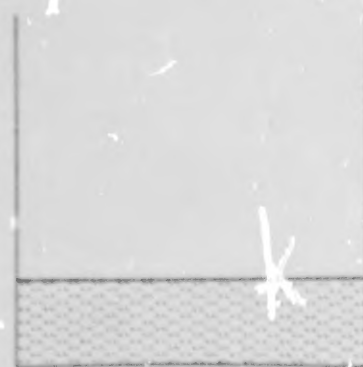
25 h.e.u.



100 h.e.u.



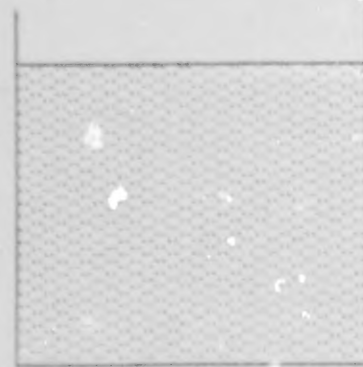
20 h.e.u.



18 h.e.u.



95 h.e.u.



100 h.e.u.

Name: _____



1. ARNOLD HAD HALF A GLASS OF WATER AT 10°C . PHIL HAD HALF A GLASS OF WATER AT 20°C . IF ARNOLD POURED HIS WATER INTO PHIL'S GLASS, COULD YOU PREDICT THE FINAL TEMPERATURE AND VOLUME OF THE MIX?

- ☐ A. YES, THERE IS ENOUGH INFORMATION.
- ☐ B. NO, BECAUSE YOU NEED TO KNOW THE TEMPERATURE OF ARNOLD'S WATER.
- ☐ C. NO, YOU NEED TO KNOW THE VOLUME OF PHIL'S WATER.
- ☐ D. NO, YOU NEED TO KNOW THE TEMPERATURE AND VOLUME OF ARNOLD'S WATER.

2. LOIS HAD SOME MILK AT 30°C . JAN HAD A QUART UNIT MEASURE OF MILK AT 60°C . THEY MIXED THEIR MILK IN A LARGE CONTAINER. CAN YOU PREDICT THE VOLUME AND TEMPERATURE OF THE MIXED MILK?

- ☐ A. YES, THERE IS ENOUGH INFORMATION.
- ☐ B. NO, YOU NEED TO KNOW THE TEMPERATURE OF JAN'S MILK.
- ☐ C. NO, YOU NEED TO KNOW THE VOLUME OF LOIS' MILK.
- ☐ D. NO, YOU NEED TO KNOW THE TEMPERATURE OF JAN'S MILK AND THE VOLUME OF LOIS' MILK.

3. MORRIS HAD COFFEE. DARRELL HAD HALF A CUP OF COFFEE AT 80°C . THEY BOTH POURED THEIR COFFEE INTO AN EMPTY POT. CAN YOU PREDICT THE FINAL VOLUME AND TEMPERATURE OF THE MIX?

- ☐ A. YES, THERE IS ENOUGH INFORMATION.
- ☐ B. NO, YOU NEED TO KNOW THE VOLUME OF MORRIS' COFFEE.
- ☐ C. NO, YOU NEED TO KNOW THE TEMPERATURE OF MORRIS' COFFEE.
- ☐ D. NO, YOU NEED TO KNOW THE TEMPERATURE AND VOLUME OF MORRIS' COFFEE.

Name: _____

1.

3 measures
10°C

+

4 measures
10°C

V

3 measures	7 measures	12 measures
---------------	---------------	----------------

T

10°C	20°C	70°C
------	------	------

2.

10 measures
5°C

+

5 measures
20°C

V

10 measures	12 measures	15 measures
----------------	----------------	----------------

T

5°C	10°C	20°C
-----	------	------

3.

10 measures
20°C

+

20 measures
20°C

+

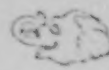
30 measures
10°C

V

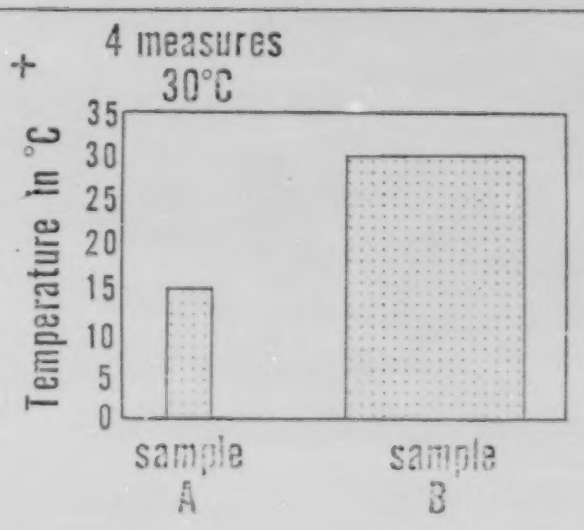
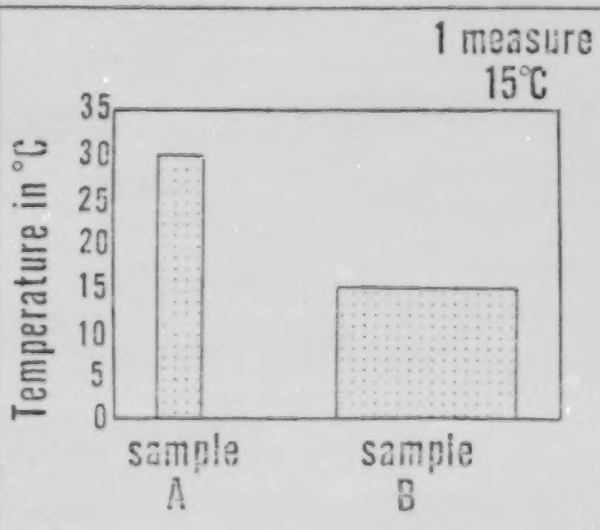
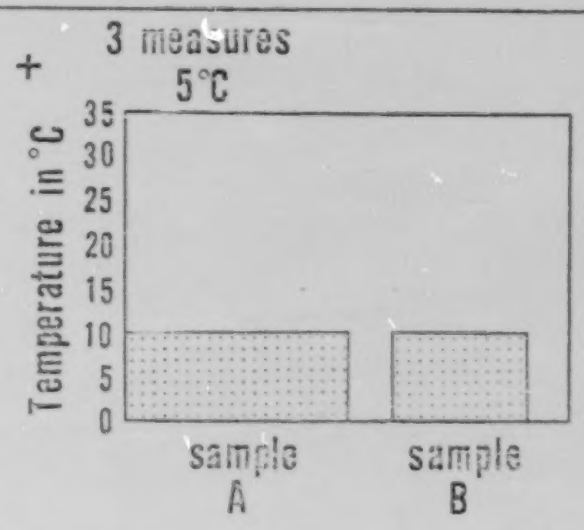
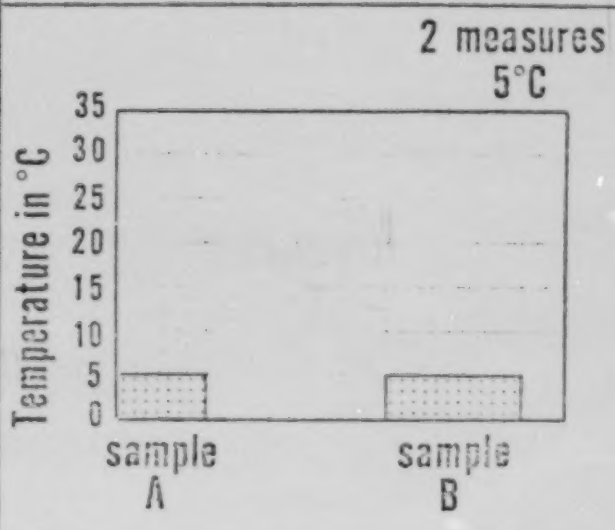
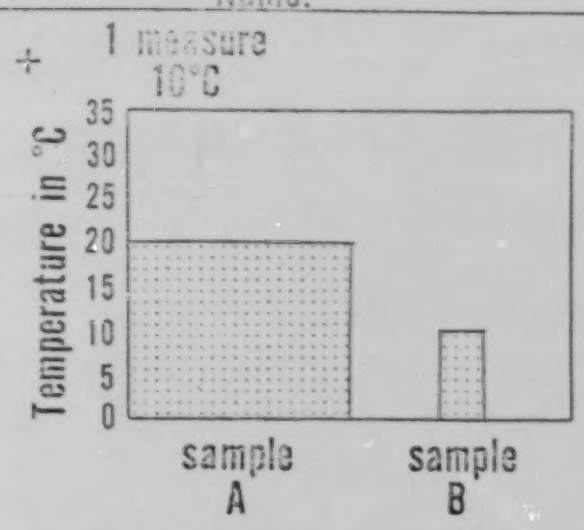
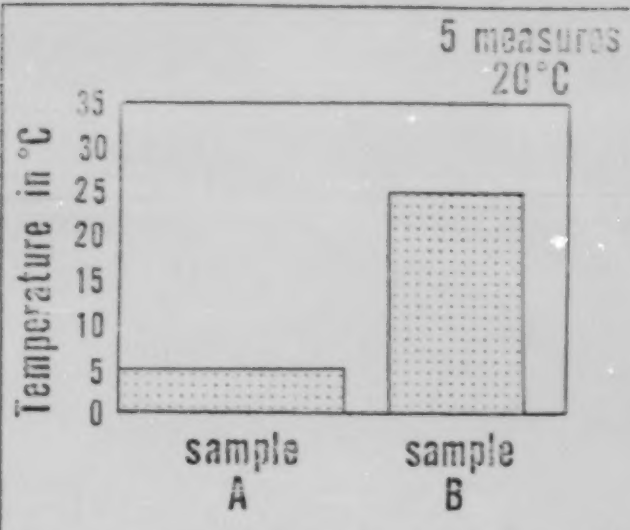
60 measures	600 measures	6000 measures
----------------	-----------------	------------------

T

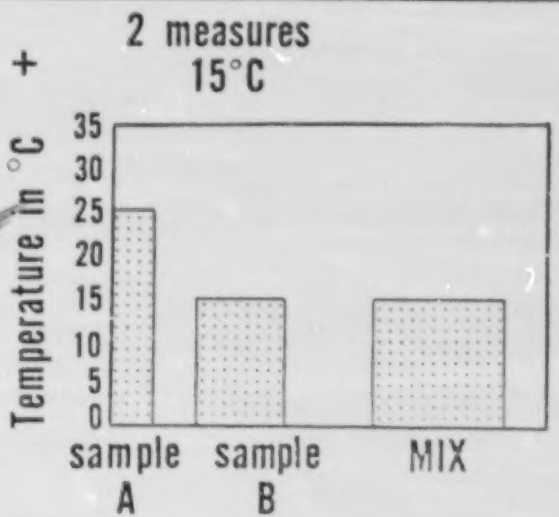
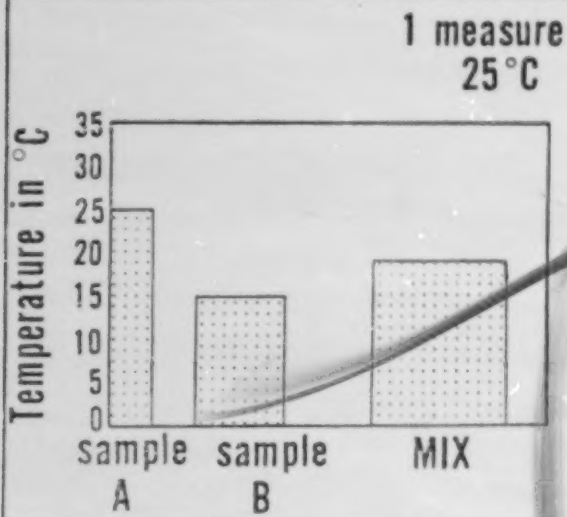
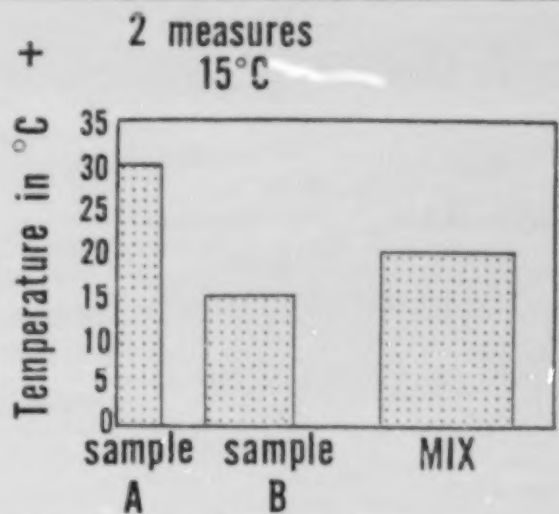
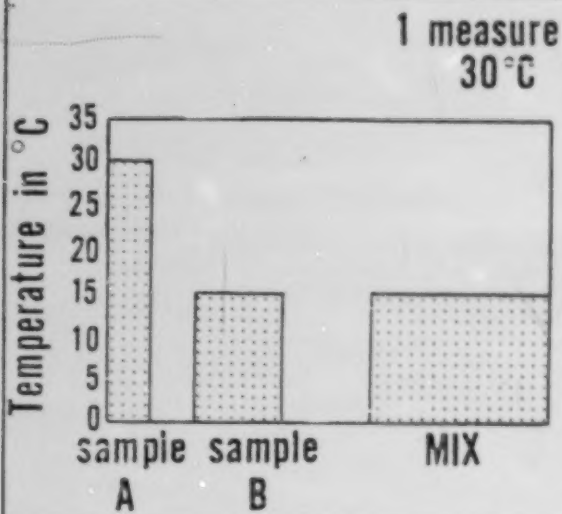
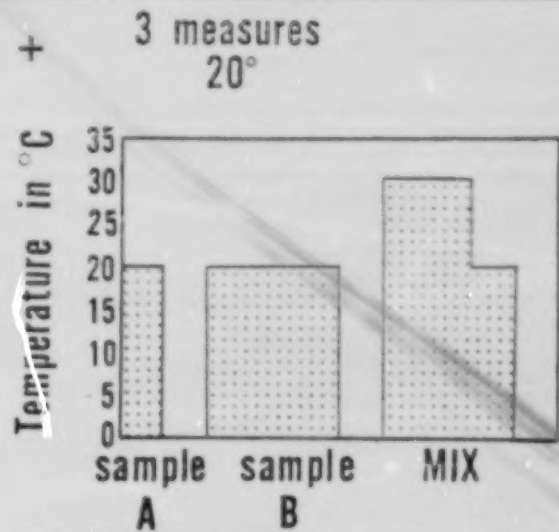
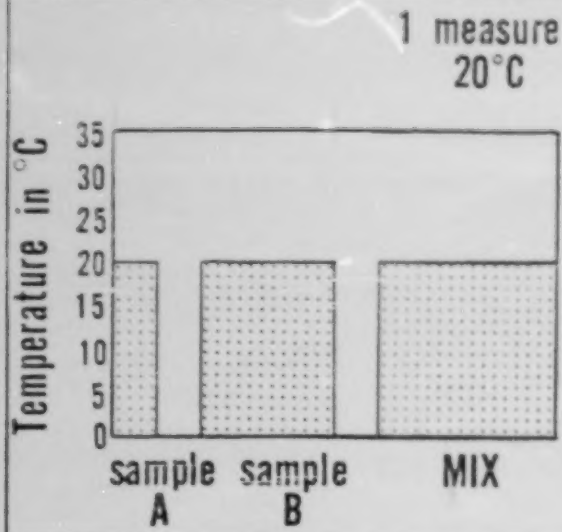
12°C	15°C	18°C
------	------	------



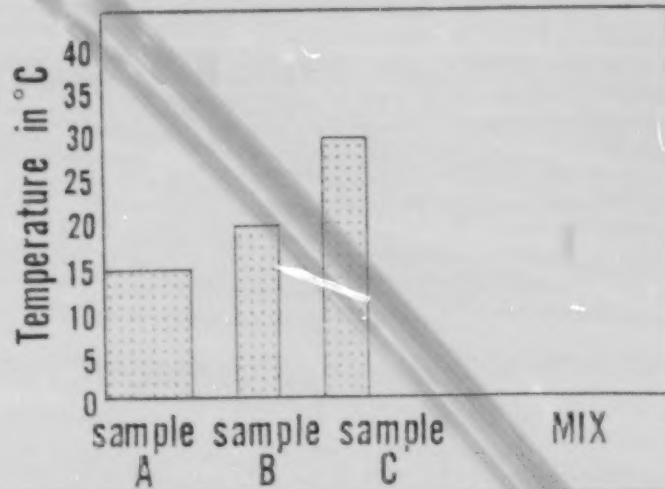
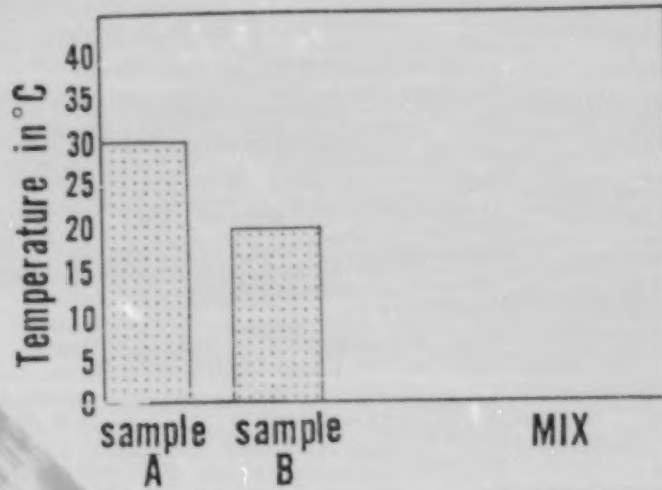
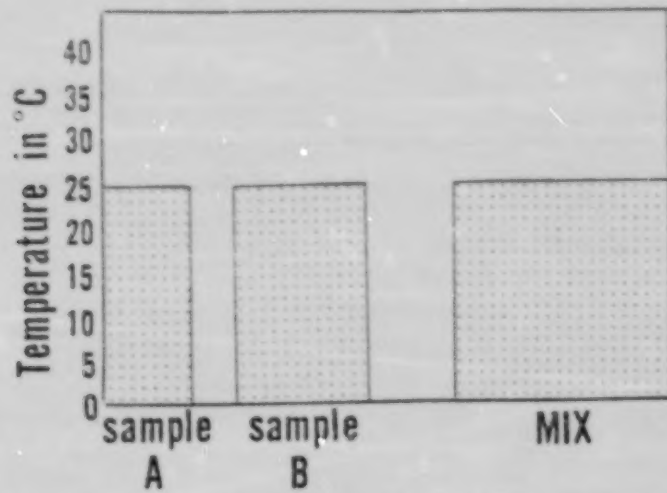
Name: _____



Name: _____



Name: _____



Selected Assessment Materials from
the Teacher's Guide for Grade Five

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Minisequence I Assessments

Screening Assessments

The concepts being tested in this Minisequence are:

- a. All plants and animals are made up of cells.
- b. There may be different kinds of cells within the same plant or animal.
- c. Cells contain different substances within them which perform various functions.

In this Assessment, there is only one Part, covering all three concepts. Distribute the two assessment pages to the children. Have them write their names in the appropriate place. This assessment will take about 5 minutes.

The assessment pages are in alphabetical order for an entire Minisequence. The letters, which appear in the upper right hand corner of each page, allow the children to identify the page they are to work on at any given time. The letters also permit you to maintain the correct order in collating the pages. The pages may be collated in groups, Part 1, Part 2, etc.--sometimes the children appreciate the change of pace afforded by collecting one set of papers and passing out the next. The pages may also be distributed as a complete set for the Minisequence.

In the assessments, suggested instructions to be read to the children appear in capital letters, as do the problems themselves. After distributing the assessment pages, read the instructions and then the problems, one by one, together with the possible responses. The children should read the problems along with you, silently, and then circle the letter of the best response. They should be encouraged to think out their responses and not to guess.

We have tried to use language at the level suggested in the Activities themselves. In some problems, however, a child may ask for the meaning of a particular word. If, in your judgment, your answer would provide the answer to the problem, you should decline, considering that he or she does not know the concept being assessed. If you can answer the child simply, without disclosing the answer to the problem itself, you may do so. As a general

rule, you should ask the child to respond stating what he or she thinks the word means.

Page A

Ask the children to turn to page A.

1. IF YOU EXAMINE A THIN SLICE OF AN APPLE AND THE LEAF OF AN APPLE TREE UNDER A MICROSCOPE, YOU WOULD FIND THAT THEY ARE BOTH MADE UP OF

- A. STARCH.
- B. CELLS.
- C. GREEN PARTICLES.

2. WHEN YOU STUDY THE CELLS FROM TWO DIFFERENT PARTS OF A PLANT, YOU WILL PROBABLY FIND THAT THE CELLS

- A. DIFFER IN SIZE AND SHAPE.
- B. HAVE THE SAME SIZE AND SHAPE.
- C. ARE NOT AT ALL ALIKE.

3. CELLS WITHIN THE SAME PART OF A LEAF

- A. ALWAYS LOOK EXACTLY THE SAME.
- B. HAVE MANY DIFFERENT SIZES AND SHAPES.
- C. USUALLY LOOK A LITTLE DIFFERENT FROM EACH OTHER.

4. CELLS ARE

- A. LARGER THAN MOLECULES.
- B. SMALLER THAN MOLECULES.
- C. THE SAME SIZE AS MOLECULES.

5. CELLS CAN BE FOUND

- A. ONLY AS PARTS OF PLANTS.
- B. ONLY AS PARTS OF ANIMALS.
- C. AS PARTS OF BOTH PLANTS AND ANIMALS.

Page B

NOW TURN TO PAGE B.

6. THE CELLS IN A LEAF
- A. ARE THE SMALLEST PARTICLES IN THE PLANT.
 - B. MAY HAVE SMALLER PARTICLES WITHIN THEM.
 - C. HAVE THE SAME SIZE AND SHAPE.
7. IF YOU LOOKED AT POTATO AND BANANA CELLS UNDER A MICROSCOPE, YOU WOULD FIND THAT
- A. THEY ARE EXACTLY THE SAME BECAUSE BOTH CONTAIN STARCH.
 - B. THEY LOOK VERY DIFFERENT BECAUSE THEY COME FROM QUITE DIFFERENT PLANTS.
 - C. THEY ARE ALIKE IN HAVING WALLS SEPARATING THEM AND MATERIAL INSIDE THEM.
8. PHILIP FOUND A LONG, VERY THIN THREADLIKE PIECE OF GREEN MATERIAL IN A SAMPLE OF WATER HE HAD TAKEN FROM A POND. SINCE IT WAS GREEN HE THOUGHT THAT IT MIGHT BE SOME KIND OF A PLANT. HIS FRIENDS SUGGESTED THE FOLLOWING AS THINGS HE MIGHT DO TO FIND OUT FOR SURE. WHICH ONE DO YOU CONSIDER TO BE THE BEST SUGGESTION?
- A. USE A MICROSCOPE TO FIND OUT IF IT HAS LEAVES THAT CAN BE USED TO MANUFACTURE THE FOOD IT NEEDS.
 - B. USE A MICROSCOPE TO FIND OUT IF IT HAS ROOTS THAT CAN BE USED TO TAKE IN THE WATER IT NEEDS.
 - C. USE A MICROSCOPE TO FIND OUT IF IT IS MADE UP OF CELLS CLEARLY SEPARATED BY CELL WALLS.
9. IN AN ANIMAL, CELLS ARE
- A. MANY DIFFERENT SHAPES AND SIZES.
 - B. ALIKE IN THAT THEY HAVE A WALL AND MATERIAL INSIDE.
 - C. BOTH A AND B ARE TRUE.

1. IF YOU EXAMINE A THIN SLICE OF AN APPLE AND THE LEAF OF AN APPLE TREE UNDER A MICROSCOPE, YOU WOULD FIND THAT THEY ARE BOTH MADE UP OF
 - A. STARCH.
 - B. CELLS.
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 - A. DIFFER IN SIZE AND SHAPE.
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- A. MANY DIFFERENT SHAPES AND SIZES.
- B. ALIKE IN THAT THEY HAVE A WALL AND MATERIAL INSIDE.
- C. BOTH A AND B ARE TRUE.

2

APPENDIX F
EXHIBITS OF DISSEMINATION MATERIALS

Bibliography of Articles Related to COPES

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Announcement of the Publication
of COPES Teacher's Guides

COPES

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COPES, the new elementary science curriculum for the seventies, announces yet another Guide in its series.

The Teacher's Guide for Grade 5 is now available. As in grades 3 and 4, the teaching activities are divided into short "mini-sequences," each of which focuses on a set of closely related concepts supporting one or more conceptual schemes. Development within each mini-sequence and within the grade as a whole is sequential with respect to science content and to the manipulative and conceptual skills of the children. The grade 5 activities build on the teaching materials presented in the previous volumes. Whenever appropriate in the Guide, references are made to the prerequisite concepts and skills developed in earlier grades.

As in the other volumes, readily available equipment and materials are used in all activities. Assessment materials are an integral part of the Guide. They are designed to evaluate group achievement and to provide additional teaching materials for those children who need more experience. Tear-out sheets for ease in duplicating the assessments and worksheets are included at the end of the Guide.

Other materials available:

- Teacher's Guide for the Grade 4 Sequence.
- Teacher's Guide for the Grade 3 Sequence.
- Teacher's Guide for the Grade 2 Sequence.
- Grade 2 Assessment Kit includes separate assessment and worksheet pages from the Teacher's Guide for ease in duplicating.
- Teacher's Guide for the K-1 Sequence.
- Assessment Kit for K-1 as for Grade 2 above.
- A K-6 Teacher's Guide for a Conservation of Energy Sequence, as developed during the COPES pilot study.
- The Water-Mix Experiments, a single-concept booklet consisting of fifteen activities, usable above grade three. This booklet and an optional equipment kit are available from American Science and Engineering, 20 Overland Street, Boston, Mass. 02215.

The Grade 5 Sequence

Cells: Units of Structure and Function

Introduction to the Microscope
Plant and Animal Cells
Changes Inside Banana Cells

Doing Some Work

A Rolling Marble
What Can a Rolling Marble Do?
What is "Work"?
Kinetic Energy
Potential Energy

Heat Energy and Liquefying Solids

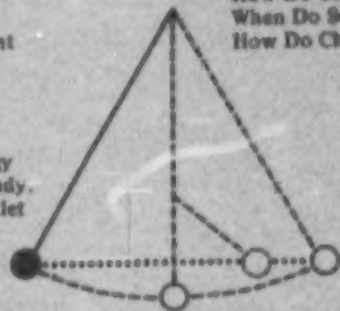
Melting and Dissolving Solids
The Disappearance of Heat Energy
Some Properties of Salt-Water Solutions
The Reappearance of Heat Energy

Energy Transformations

Radiant Energy to Heat Energy
Chemical Energy (Batteries) to Heat Energy
Chemical Energy (Food) to Heat Energy
Kinetic Energy to Heat Energy

Investigating Populations

Selecting Marbles
Tossing Cubes
How Do Thumbtacks Land?
When Do Seeds Germinate?
How Do Chemicals Affect Germination?



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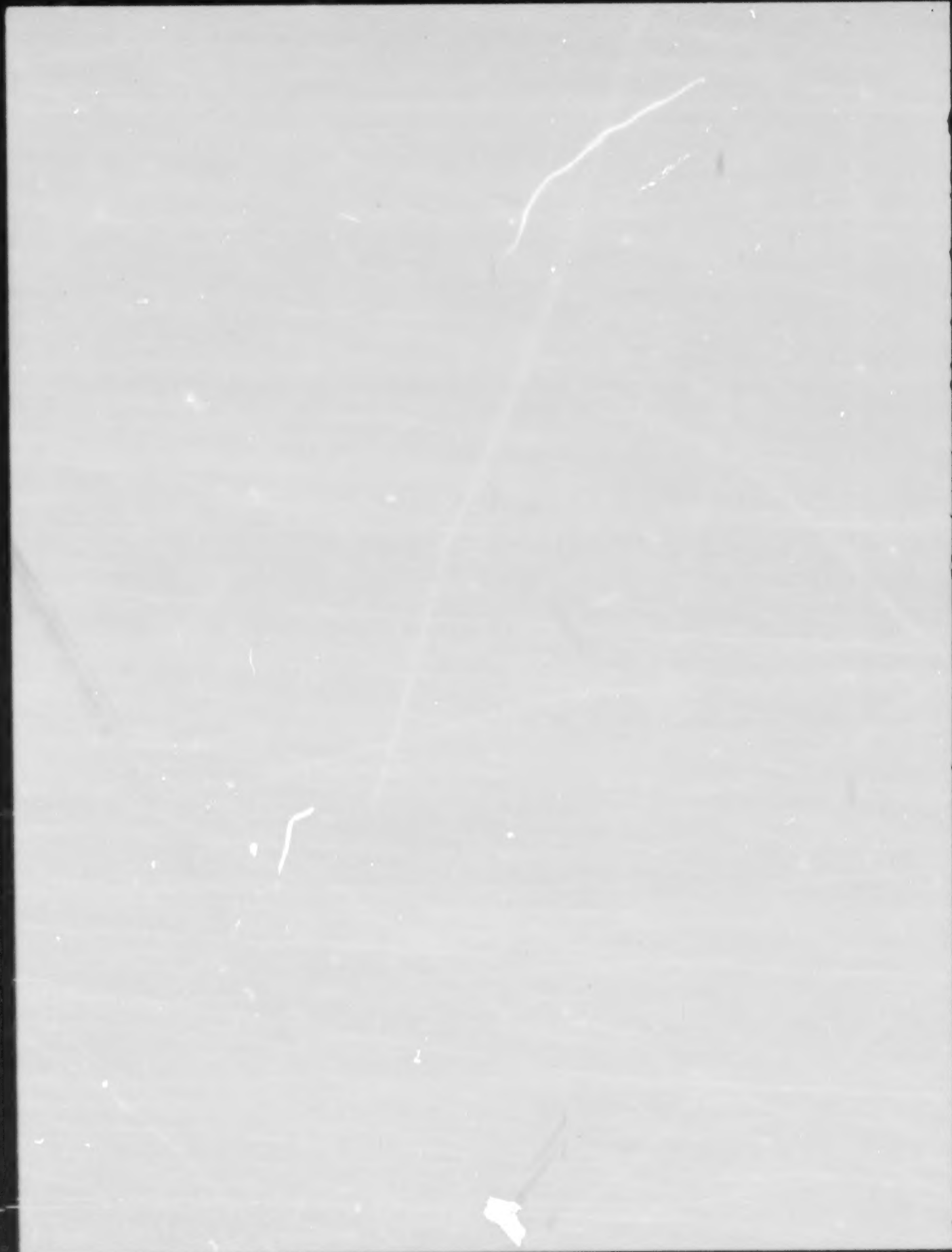
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COPES Newsletter, No.4, March 1970



COPEs

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Newsletter, No. 4

March 1970

COPEs has made a good deal of progress since issuing its previous "Newsletter" (March 1968). All the conceptual schemes that will serve as the foundation of the complete program have now been identified, and more than half the activities have been developed and tested in the COPEs Laboratory School. It is expected that the full complement of activities will be developed by the beginning of 1971, and that the teacher's guides will be completed by September 1971.

The five conceptual schemes that were selected to form the core of the COPEs program are: The Structural Units of the Universe, Interaction and Change, The Conservation of Energy, The Degradation of Energy, and The Statistical View of Nature. These are more fully described in the COPEs brochure (March 1969 or November 1969). The staff believes that all of elementary science that might be regarded as being truly significant can fit into one or more of these five conceptual schemes.

In addition, a number of skills or processes of science have been selected as requisite to the overall COPEs program. Each activity in the program involves both science process and science content, the latter aimed at developing an understanding of the basic conceptual schemes.

As described below in greater detail the full COPEs program will be contained in three teacher's guides, the first of which (grades K-2) will be available later this year. It is now possible to estimate the cost of the COPEs program in an elementary school. Assuming that major items of equipment, such as microscopes, balances, etc., have a useful life of five years, the per pupil cost (including major items and expendables) is estimated at about one dollar per year. Every effort has been made to specify simple equipment, most of which is readily available locally or at reasonable cost from laboratory supply houses. Packaged kits will not be necessary for the COPEs program, although some equipment suppliers may choose to provide complete sets of COPEs equipment for those schools that prefer to purchase supplies in this way. However, an individual teacher or school should have no difficulty in obtaining most of the needed equipment locally.

COPEs FROM A BIOLOGICAL POINT OF VIEW

Biology is contributing an integral part to the COPEs curriculum. The COPEs biology team is approaching its objective in three ways: it has proposed a number of basic biological concepts related to the COPEs conceptual schemes, developed and tested pupil activities to demonstrate these biological concepts, and developed a number of biological activities that serve to supplement the concepts previously developed in the physical science portion of the curriculum. The objective of this approach is to encourage children to think of biological phenomena in terms of the basic conceptual framework adopted by COPEs.

In deciding what biological content to include in the COPEs curriculum several factors have been considered. Of primary importance is the simple fact that COPEs is not oriented toward teaching biology, chemistry, physics, or earth science, but science as a whole. It is not applied science. COPEs is designed to teach a limited number of concepts which are useful in understanding our natural environment. Furthermore, the program places major emphasis on an "activity approach." The biology content must therefore meet the following three criteria: (a) it must be easily handled as an elementary school classroom activity, using only readily available materials; (b) it must not be trivial; and (c) it must fit into the COPEs framework.

We think that each of the following biological concepts fulfills these criteria, and is, therefore, suitable for the COPEs program.

Organisms grow and develop.

The growth and development of organisms are familiar phenomena to K-3 children. Within the COPEs spiral these phenomena will be approached first from the viewpoint of interaction and change. At higher levels in the program the concept of organisms growing and increasing in order and organization will be introduced.

Evolution results in a diversity of organisms.

Diversity of organisms will be introduced at the K-3 level of the sequence. As children progress in sophistication through the sequence, they will come to understand that certain organisms share common properties and can be divided into groups on this basis. From this point the idea of evolutionary change will be introduced and will be supported with background materials from activities in The Statistical View of Nature and Interaction and Change.

(Continued on page 6)



THE KINDERGARTEN-GRADE 2 SEQUENCE

In developing the K-2 portion of the COPES curriculum, we are concerned that the proposed materials reflect our conviction that young children continually interact with and interpret phenomena in their environment, provided the phenomena are challenging. Thus, we are using as one criterion in selecting an activity whether an appeal or a challenge factor is clearly present. Further, children at the grade level for which an activity is intended must be capable of completing it successfully. For this reason, an activity must be tested and retested in classroom situations until a satisfactory revision is achieved—or until it is discarded.

Each activity also must be a significant component in a series designed to build those introductory concepts that are basic to developing understanding of the five conceptual schemes that form the core of the COPES Sequence (grades 3-6).

It was determined that the introductory concepts that ought to be developed in grades K-2 probably should cluster around three basic ideas—Descriptions of Matter and Energy, Matter and Energy Interactions, and Variability. Additional analysis resulted in delineating seven introductory concepts, each of which is related to one of the three fundamental ideas indicated above. Thus, a second criterion used in selecting activities is that each must contribute to the development of one or more of the introductory concepts listed below.

The K-2 Introductory Concepts	
Fundamental Ideas	Introductory Concepts
Descriptions of Matter and Energy	1. All objects can be characterized either as living or nonliving. 2. Objects (living and nonliving) are made up of discrete parts. 3. Objects and their parts are composed of matter. 4. Different objects may exhibit different degrees of order in the relationship of their parts.
Matter and Energy Interactions	5. Objects (living and nonliving) interact with their surroundings (environment) to produce observable changes. 6. Adding or removing energy from an object causes changes in one or more properties of the object.
Variability	7. The observed properties and changes that occur in a group of similar objects (sometimes called a "population") exhibit some variability.

It should be noted that activities related to Descriptions of Matter and Energy and to Matter and Energy Interactions will be presented in all three grades, at increasing levels of sophistication. Activities related to Variability will be developed only in grades 1 and 2. Hence, the organization of materials at the K-2 levels is in a spiral arrangement.

The third criterion employed in selecting an activity is that it furnish an opportunity for children to be introduced to and/or to practice one or more of the nine skills selected for development in the COPES curriculum for kindergarten through grade 6. These skills are: Analyzing, Classifying, Communicating, Experimenting, Interpreting, Mathematical Reasoning, Measuring, Observing, and Predicting. Again, it should be noted that children will be using these skills at increasing levels of sophistication as they move from grade to grade. For example, measuring will be introduced in kindergarten and grade 1 largely in terms of whether an object is longer than, warmer than, heavier than, smaller than, etc., another object. Subsequently, children will use increasingly more sophisticated methods of measuring, including the use of instruments.

It should be apparent that the K-2 portion of the COPES curriculum is a necessary component for it is here that introductory concepts basic to the conceptual schemes are developed, and it is here that the nine skills are introduced.

Although the sequence is not yet in final form, a clearer picture may emerge if we consider the tentative sequence for the kindergarten. At present, activities selected for this level have been organized around four topics: Living and Nonliving Things, Descriptions of Things, Changes, and Sizes and Amounts. The introductory concepts, supporting concepts, and skills for two of these topics follow.

Topic: Living and Nonliving Things

Introductory Concept:

All objects (things) can be classified as either living or nonliving.

Supporting Concepts:

1. There are many different kinds of things in our surroundings.
2. Some things are alive and some are not.

Skills: Classifying, Communicating, Observing.

Topic: Changes

Introductory Concepts:

1. Objects (living and nonliving) interact with their surroundings (environment) to produce observable changes.
2. Adding or removing energy from an object causes changes in one or more properties of the object.

Supporting Concepts:

1. We use our senses to detect motion.
2. Objects can be moved by pushing and pulling.
3. A magnet can be used to move some things.
4. Magnets push and pull each other.
5. Heat energy can be used to melt some things.
6. Changes occur in some foods as they interact with water.
7. Changes occur in some foods when heat energy is added during the cooking process.
8. Living things change over periods of time.

Skills: Communicating, Experimenting, Interpreting, Observing.

It is anticipated that the final K-2 sequence will include approximately 60 activities distributed as follows: kindergarten (20); grade one (25); grade two (35). The tentative publication date for this portion of the COPES curriculum is early fall of this year.

[illegible]

Evaluation of COPEs activities is receiving increasing emphasis along two lines this year. With regard to children's mastery of the concepts presented in the COPEs activities, new evaluative modes stress the child's development of his own expectations from an activity and his explanations of what he observes, in addition to the necessary but insufficient goal of "getting the right answer." The emphasis is on "mastery" of one concept as a necessary preliminary to the learning of collateral or more general concepts. This criterion-oriented assessment differs in principle from the usual assessment that typically results in differentiating one child's accomplishments from those of his peers.

A second emphasis is internal to the development of new activities. The model shown depicts a system of interactions of staff members with differing competencies and goals, all bearing on the psychologically complex product that is COPES activity. The upper portion of the chart shows that an idea is evolved from a science context and evaluated for how the child is likely to react to it ("assimilate it," in Piaget's words). Then it is presented to an experienced teacher who has the requisite skills and knowledge of science for a judgment of its feasibility in a classroom setting (Y, of course, means *yes* and N, *no*). After all the staff agree on its scientific validity, psychological assimilability, and teaching feasibility, the unit is presented to children in a classroom setting. The children's performance, shown along the bottom portion of the model, is evaluated in light of their aptitudes and other inputs to the learning experience.

If, in terms of the final assessment, learning has occurred—the children have mastered the concept—the unit is added to the curriculum. The bottom line represents the final test, not planned for this year, in which the COPE curriculum is compared with other methods of teaching science.

During the past year, new activities have been evaluated by the scheme outlined in the upper portion of the chart. The thermal energy (water mix) sequence of activities has been recycled through the upper portion, with some interesting modifications resulting. That sequence is now being evaluated in terms of children's performances. Four

classrooms were selected from the Oyster Bay-Plainview area of Long Island as the site of this evaluation. Two third-grade and two fourth-grade classes are involved; two of the teachers have participated in a COPES workshop and two have not. Children's aptitudes to deal with figural and semantic (meaningful) material by categorizing it, producing it, transforming it, and seeing implications from it have been assessed by special measures devised along the lines of the structure-of-intellect model devised by J. P. Guilford and his associates.¹ These aptitudes tap much more of a child's total performance potential than the usual quite restricted tests of "verbal" and "nonverbal" ability.² The COPES evaluation staff designed the new assessment devices especially for the elementary school population (grades 3-6), and administered them to the four classrooms participating in the present study. Evaluation of the children's responses is proceeding rapidly; indications are that reliabilities of the measures will range above .85, a value that is considered high for group assessment. The children's previous knowledge was assessed by a specially devised pretest restricted to knowledge of thermal energy and related phenomena. Following the presentation of the sequence of activities, a post-test will be administered to ascertain the degree to which the experience leads to children's mastery of the concepts underlying the sequence. The final analysis and report of this evaluation are planned for early summer.

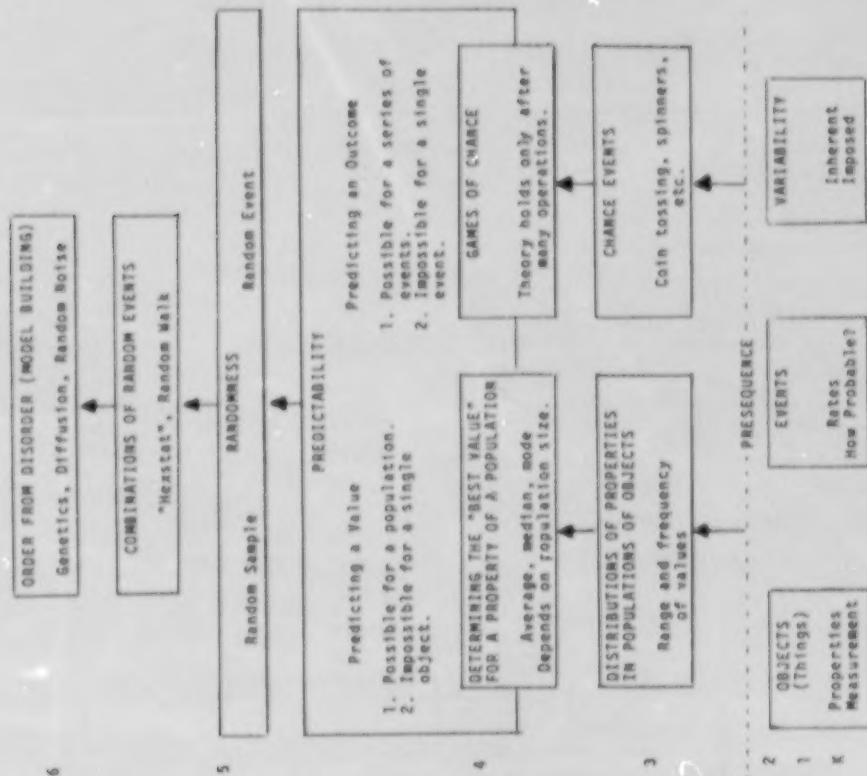
It is expected that this evaluative procedure will, with inevitable modifications, serve as a prototype for the continuing evaluation, both internal and external, of COPE activities. Subsequent efforts will incorporate the assessment of attitudes of both teachers³ and children, and the interaction of attitudes and achievement.

¹ Guilford, J. P., *Intelligence, Creativity, and Their Educational Implications* (San Diego: Knapp, 1969).

² Guilford, J. P., The Nature of Human Intelligence (New York: McGraw-Hill Book Company, 1967).

³ Kerlinger, F. N., Attitudes and Perceptions of Desirable Traits and Behavior of Teachers (U.S. Office of Education, 1967).

COPIES
TENTATIVE SEQUENCE
THE STATISTICAL VIEW OF NATURE



LABORATORY SCHOOL

Based on prior experience in developing teaching materials for our pilot study, we have found it essential to test tentative activities and sequences under laboratory school conditions. Our need for "instant children" precipitated the first COPES-centered Laboratory School in the spring of 1969. This proved so valuable to us that we conducted two separate laboratory sessions during the past summer which met five mornings a week and involved children from grades three through six. The daily program was conducted by two elementary school teachers who were aided by an art specialist. Mathematics materials as well as art media were coordinated with the daily science program whenever possible.

During the summer, scientists with specialties in biology, geology, chemistry, and physics were teamed with science teachers to formulate activities for *The Structural Units of the Universe* conceptual scheme. Testing was done with the entire class or with microgroups. This procedure enabled us to make revisions during and immediately following the laboratory sessions. Following is an example of such an activity which is intended as a presequence experience:

Classification

Supporting Objectives

To discover that objects with which children are familiar can be classified as living or nonliving.

Materials

1 deck of cards or a dictionary, 1 tray containing examples of living and nonliving things, or examples from within the classroom.

Suggested Instructional Sequence

1. Deck of Cards—Begin the lesson by showing the children a deck of cards. Ask them to describe several ways in which these might be divided into groups or sets. They may suggest that they could be divided into reds and blacks, into the four suits, or into numbers from various suits. (Other objects may be substituted for cards if desired.) Ask the children if they can think of why they might want or need to group these according to the suggestions that were made previously.

2. Living and Nonliving—After the discussion prompted above, display the tray which contains an assortment of living and nonliving objects. Hold up the first object (nonliving) and place it on the table. Hold up the second object (living) and place it at the other end of the table. Ask the children what differences they notice between the two objects. Continue this until the children begin to notice that the grouping seems to depend on whether the object is living or nonliving. Begin to ask for volunteers to place each item that you hold up into its proper group. Emphasize that the "rule of the game" is that they should be able to give a reason for the particular grouping upon which they decide. Encourage class interaction through discussion.

3. Variations—Instead of the tray of materials the teacher may wish to use objects in the classroom. A class scrapbook might be started and continued for a longer period of time. The bulletin board is also a good medium if discussion is initiated relating to the objects brought in and placed on the board.

This semester we are meeting with youngsters who were recruited from schools within a fifteen-minute walking distance of New York University. The children meet with us twice a week from 3:30 to 4:45 p.m. We are presently testing the sequences that deal with the concepts relating to *The Structural Units of the Universe*. Each session is taped and responses are carefully analyzed by the COPES staff. At least one member of the Evaluation Team and a scientist are present during each class period. The fifth and sixth grade children who are participating in the Laboratory School find themselves in the unique role of critic. They are encouraged to respond fully to those activities which they feel are most meaningful and to indicate any difficulties they encounter. All of the above enables us to get immediate feedback, which is so vital in a testing program such as ours.

TRI-UNIVERSITY PROJECT AND COPES

New York University has been one of three universities engaged in a major project designed to improve the effectiveness of selected teachers of prospective elementary school teachers. During 1969-1970 N.Y.U.'s part of the Tri-University Project is concentrating upon science and mathematics education. The project is funded by the U.S. Office of Education.

Selected professors of science education and professors of science from five colleges are participating in the postdoctoral component of the program. Six selected experienced science teachers are enrolled in the predoctoral component, which leads to the doctorate in science education with a specialty in elementary school science.

The COPES staff, its facilities, and its cooperating elementary schools are among the several institutional and community resources being used in the Tri-University Project at N.Y.U. The opportunities that Tri-University participants and COPES staff have had to interact with respect to their mutual interests in elementary school science has greatly benefited the COPES program. COPES materials will be used in all the predoctoral research projects. The postdoctoral participants will be including COPES in their teacher education programs. Furthermore, their home institutions may also serve as field testing centers for this new curriculum.

FUTURE PLANS

Sequences of definitive activities for the last two conceptual schemes, *Interaction and Change* and *Degradation of Energy*, should be completed by the end of the summer of 1970. Again, a summer laboratory school will be used for the development. Although at the end of the pilot phase a Teacher's Guide covering all K-6 activities for the scheme, *Conservation of Energy*, was published,¹ we do not contemplate issuing K-6 volumes for the other four schemes. Instead, we plan to issue three volumes: K-2, 3-4, and 5-6. The last two volumes will contain sequences for each of the five schemes designed for a given grade level; logical bridging activities will provide a fully integrated, coherent, and sequential curriculum. The K-2 volume containing the activities that develop manipulative and conceptual skills required for all the schemes is being prepared now for release by September 1970.

¹ See "Newsletter," No. 3, March 1968.

COOPERATING TEST SCHOOLS

Twenty-three teachers from 17 Nassau County (New York) elementary schools are cooperating this year with the COPES staff in testing COPES activities and assessment materials in their classes. All of these teachers completed the COPES in-service course offered during 1968-1969.¹ When needed, the teachers receive consultative service from the staff. During the spring term, a number of additional teachers in these schools have indicated an interest in using the Water-Mix Experiments in their classes. This will increase considerably the number of classrooms within which COPES materials are presently being tested.

Following is a list of the cooperating Nassau County Schools.

Cooperating Nassau County Schools

School System School	Principal	Teacher	Grade
Bethpage			
Bloomfield	Mr. V. Miller	Mrs. S. Seegrist	3
Charles Campagne	Miss M. Quinn	Mrs. M. Manger	4
Locust Valley			
Locust Valley Intern.	Dr. A. MacArthur	Miss J. Ehrlich	3
		Mr. L. Dransow	6
Oyster Bay			
Thos. Roosevelt	Dr. D. Rovense	Mrs. G. McEvoy	3
		Mr. W. Roichert	Concl.
Plainville			
Baldwin Drive	Mr. L. DiGiovanni	Mr. S. Rifkin	5
John R. West	Mr. R. Schenberg	Mrs. M. Rothberg	3
Schwartz	Mr. P. Maringolo	Mrs. S. November	4, 5
		Mrs. H. Soudry	6
Plainview			
Joyce Road	Mr. M. Witte	Mr. S. Dowdle	5
		Mr. R. Krupp	6
		Mr. L. Shors	6
Mametto	Mr. J. Brooks	Miss A. Dean	1
		Mrs. B. Polifka	3
Old Bethpage	Mr. M. Fennel	Mrs. E. Lynn	3
Oak Drive	Dr. F. Karpman	Mr. D. Rosenfeld	5
		Mrs. M. Sharfstein	6
Parbury	Mr. M. Zarembo	Mrs. N. Savage	1-3
Pasadena	Mrs. I. Miller	Mrs. R. Leonard	4
		Mrs. R. Ferrone	4
Sea Cliff			
Sea Cliff Elem.	Mr. C. Sloan	Mrs. A. Feltz	3
Syncoet			
Village	Miss V. Chan	Mrs. R. Davis	3
Valley Stream			
Forest Road	Mr. M. R. Mary	Mr. R. Kaufman	6
Westbury			
Dryden St.	Mrs. V. Profeta	Mrs. M. McNally	4

COPES PAMPHLET SERIES

A great many elementary school teachers have indicated an interest in using selected sequences of activities from the COPES teaching materials in their science classes. They want to use them now, rather than wait until the program is completed. To accommodate this interest we plan to prepare a series of pamphlets dealing with selected, class-tested sequences of activities.

The first pamphlet, entitled Water-Mix Experiments, has been completed. It is suitable for use at the third-grade level or above. It contains fourteen activities that develop, in a step-by-step sequence, an understanding that heat energy is conserved when samples of water are mixed. Three sets of assessment materials are included. These are to be used at appropriate places through the sequence to assess the development of essential skills and concepts.

Several sections are included in the introductory part of the pamphlet. One deals with the science implications of the selected sequence, another with the psychological basis for the conceptual approach; and the third is a general commentary on the strategy of carrying on the activities.

If you are interested in obtaining a copy of this pamphlet, please write to the director of COPES for further information.

(Continued from page 1)

There is a fundamental similarity (unity) in the structural and functional organization of organisms.

The idea will be stressed that despite the outward appearance of diversity and variability, organisms exhibit a similarity in terms of structure and function. As this concept develops through the curriculum it will contribute primarily to the conceptual scheme having to do with The Structural Units. Children will learn, at the K-2 level, that all multicellular organisms are composed of organs. An important part of this sequence will be the "discovery" of cells, which, in turn, will contribute to the sequence on The Structural Units of the Universe. Concepts dealing with higher levels of biological organization, including populations and ecosystems, will be related to The Statistical View of Nature and to Interaction and Change.

Organisms interact with their environment.

The biological concept to be developed is that organisms are continuously interacting with their physical and biological environment. Children's understanding of this concept is dependent upon the development of the following four basic concepts: environment, stimulus, response, and interaction. We anticipate that the activities for this sequence will contribute primarily to Interaction and Change.

¹ See "Newsletter," No. 3, March 1968.

The COPES NEWSLETTER is published by the staff of the Conceptually Oriented Program in Elementary Science, New York University, 4 Washington Place, New York, N.Y. 10003.

Morris H. Shamos, Director

J. Darrell Barnard, Associate Director

Report from the State University of
New York College at Geneseo

"Some Reactions of College Students
to Classroom Use of COPES Materials"

Some Reactions of College Students to Classroom Use of COPES Materials

During the spring of 1973, fifteen students of teaching science in the elementary schools from SUNY at Geneseo taught selected COPES lesson sets on two age-grade levels in the local campus school, the Holcomb School. They worked in pairs, teaching for two weeks at the first or second grade level and two weeks at the third, fourth, or fifth grade levels. During each two week sequence of ten hours (including classroom site preparations and cleanup), only one student worked by herself and all worked at least one sequence with a partner. In four out of eight classrooms most of the children received a total of about fifteen hours of COPES instruction in a continuous set of sequential activities over a four week period. One class of third graders and one of fifth graders received only some ten hours of instruction. In three classrooms small groups of selected children received fifteen hours or so of instruction: two in the fourth grade and one in the second. Regular teachers were present but not usually active in teaching COPES in all but two of the classrooms. There only small groups were taught COPES. Dr. Oakes moved from classroom to classroom assisting with materials, occasionally talking with children at work, or just observing. Since all but three of the college students who worked in pairs had previously had one semester of student teaching, they were able to provide most of their own evaluation. The three college students who had not had student teaching were paired with students who had.

The comments that follow are derived from lists of strong and weak points of COPES submitted independently by the college students following classroom discussions of the experiences. Certain biases of the instructor have undoubtedly made their way into the comments.

Some general reactions

Pupil interest in COPES activities was high and the meaningful science activities seemed to reinforce the concepts to be learned. Those lessons in which the children were active in using materials to "discover" ideas were especially good. Although the COPES choice of activities and concepts was generally appropriate to the age-grade level for which it was intended, the activities and goals on the primary level tended at times to undershoot the mark, while those at the intermediate level to overshoot it.¹

The physical materials which COPES suggested for use in lesson activities seemed adequate, varied, and easily obtainable locally, but sometimes became a quantitative hazard requiring excessive preparation in terms of collection and storage in the classroom.² Sometimes alternatives to the suggested materials were easily found, but it would help if COPES were to list alternative materials and places in which to look for them.

-
1. It should be noted that the materials were used in a graded school, the Geneseo Campus School, which is moving rather unevenly toward use of the open classroom.
 2. Teachers using COPES from year to year may not have this problem.

In general, student teachers and pupils met with success in using COPES materials and the teachers in whose classrooms they were used were impressed with the activity and interest of the pupils, even though the group had some hard moments.

Comments on the structure of COPES

Student teachers liked the overall sequencing of the lesson sets and the flexibility of use possible with COPES. The performance objectives, the introductions, the learning activities, and the assessment activities were praised by students. The assessment activities in particular were reported to stimulate student teachers to devise new assessment or learning activities.

While a few students seemed to feel that the lesson sets were well structured for the beginning teacher, most felt that the lesson structure or format was too restrictive. The provision of sequenced questions and predicted answers in each lesson hemmed them in to an uncomfortable degree. A more positive approach was suggested during class discussions. The sequences of teacher questions might be omitted after the first few lessons in each set of lessons. Teaching procedures that described a "discovery" route to the learning goals and that encouraged alternative creative activities for reaching the goals could then be written for each subsequent lesson or set of lessons. Although some of the student teachers were able to provide new and different ways of helping children reach COPES goals in an active fashion, some could not.

A number of the student teachers with limited science backgrounds thought COPES should provide background materials for teachers about the science concepts or ideas to be taught along with a brief list of references. Such materials could be presented at the beginning of each topic. Since the group was not able to move vertically through any of the major concept sequences of COPES, these comments deal specifically with the limited science ideas presented in given topics at given teaching levels.

An outstanding weakness of COPES

A major criticism of the group concerned the teacher oriented demonstrations and student activities that seemed to be designed for the concurrent use of all the students. The student teachers liked the individual activity idea and felt it was important for learning many science concepts and skills. There seemed to be, however, too little provision of socializing experiences that underly sciencing as a social process. Thus, COPES needs to attend to this aspect of learning by moving toward a more extensive inclusion of social learning experiences as the sequences unfold during the childrens' elementary school years.

Coupled with a tendency for many of the COPES activities to be teacher dominated and cognitively oriented, this omission bodes ill for the increased use of COPES in open class settings on the one hand. On the other, it may help to move COPES into the many slowly changing child oriented and semi-traditional elementary schools that can be found throughout the country. The provision of social experiences constitute a major philosophical thrust in American education. Either the COPES staff has not assumed a philosophical stance on this issue or the student teachers and their instructor failed to get the message.

A last word

For the most part, the student teachers and the children enjoyed using COPEX materials. The evaluation lessons indicated the children were getting the messages in the limited number of topics used. The preparations were more than most of the student teachers bargained for, but they did them and did them well. This paid off in positive results so that things went better as time passed. Most of the comments made by the teachers and the student teachers were positive. The negative comments were largely constructive. With another round of alteration, COPEX could become a more powerful elementary science program than it already is. This may have to be done by a team working with a commercial publishing house.

APPENDIX G
COPY OF REQUEST FOR PROPOSALS (RFP)



NEW YORK UNIVERSITY

COPES—Conceptually Oriented Program in Elementary Science

4 WASHINGTON PLACE, ROOM 503, NEW YORK, N.Y. 10003
AREA 212 598-3735

REQUEST FOR PROPOSALS (RFP)

for the publication and distribution of COPES Teacher's Guides
including requirements and criteria for selection

INTRODUCTION

New York University solicits proposals from publishers of educational materials for the world-wide publication and distribution of COPES Teacher's Guides, which are being developed under a contract with the U.S. Office of Education (USOE) Department of Health, Education and Welfare, with supplementary support from the National Science Foundation.

Under the Copyright Program of the USOE, as set forth in its Copyright Guidelines dated May 9, 1970, this University has been authorized to select a publisher, and enter into an agreement with that publisher, for the publication and distribution of these materials, under copyright, on an exclusive basis, for a period of five years, provided that all of the requirements of the Copyright Guidelines are met. The principal requirement is for the selection of a publisher on a competitive basis.

DESCRIPTION OF MATERIALS

The materials to be published constitute seven elementary school teacher's guides, Kindergarten through Grade 6, for the Conceptually Oriented Program in Elementary Science (COPES). Each of the guides consists of teaching materials designed to direct the learning of children toward a progressively sophisticated understanding of five conceptual schemes in science. The five conceptual schemes are the organizing themes of this new elementary science curriculum. The guides include scientific and educational background materials for the teacher, suggested instructional procedures accompanied by commentary for the teacher, pupil assessment materials, pupil worksheets, and consolidated lists of needed materials and equipment. No commercially fabricated kits are presently being recommended. (See Appendix A for the tables of contents of guides thus far published as preliminary editions.)

HISTORY OF DEVELOPMENT

The materials have been developed over a six-year period, as an all-university project, under the directorship of Morris H. Shamos, Professor of Physics. To date the USOE has funded the project in the amount of approximately one million dollars. Supplementary support amounting to about \$84,000 has been given by the National Science Foundation. New York University and other local contributions have amounted to approximately \$110,000.

During a two-year pilot phase the feasibility of the conceptual schemes approach to the development of a K-6 science curriculum was demonstrated by using control and experimental classes in two elementary schools. During the current development phase children in the COPES Laboratory School and in both public and private schools have participated in try-outs of activities as they have been produced by teams of scientists, educators, teachers, and psychologists.

It is recommended that a two-year field test of the present preliminary editions of the teacher's guides be conducted and that the ultimate selection of a publishing company be contingent upon the company's agreement to support a part of the cost of the field test as an advance against earned royalties. Both the University and the USOE agree to waive their shares of the royalties up to this cost. (See Appendix B for additional information regarding recommendations for field testing.)

PUBLICATION GOALS

The selected publisher will:

1. Be required to revise the teacher's guides (based upon the outcome of field testing), edit, and provide appropriate illustrations and other art work. The revision will be prepared in cooperation with selected members of the COPES staff.
2. Provide adequate sales personnel to contact all elementary schools and colleges of education throughout the country.
3. Conduct regional institutes for the demonstration of COPES materials to potential users.
4. Print, manufacture, stock, catalog, advertise, promote, and sell the COPES teacher's guides.

USOE REQUIREMENTS

The selected publisher must:

1. Agree to mark each piece of the material with a legend, to be specified by the USOE, which will state the date when the materials will go into the public domain; state that the materials were developed under a grant from the USOE, but disclaim any official endorsement of the materials by USOE.

2. Agree to copyright the materials in the name of the University and to register the copyright in the U.S. Copyright Office within six months after the date of publication.

3. Agree to recognize the free right of the Government to use the materials for U.S. Government purposes.

4. Agree to permit the USOE to make periodic audits of its books of accounts relating to sales and royalties of the materials. However, the USOE would not normally expect to exercise that right.

5. Agree to the right of the USOE to require termination of the agreement in the event of noncompliance by the publisher with the publication agreement. However, a review procedure is provided for the protection of the publisher and the University.

6. Agree not to publish a revision or adaptation during the last year of the period of exclusive publication rights. Any revision or adaptation published during the first four years will be subject to the same terms and conditions as the original materials.

GENERAL REQUIREMENTS

1. The publisher will be required to pay royalties in accordance with the schedule set forth in its proposal, and to provide semiannual statements of sales and royalties. It will be required to remit royalties on a semiannual basis.

2. Appropriate termination provisions will be required.

3. Arrangements for handling infringements will be required.

4. Arrangements for handling disputes will be required.

5. The publisher will permit the University, as well as the USOE, to audit its books of accounts relative to sales of these materials.

6. The grantee will warrant the materials published, but only to the extent of any royalties which might be due or accrue after a notice of infringement or violation of other right is received.

CRITERIA FOR PUBLISHER SELECTION

1. The demonstrated capability of the publisher to accomplish an effective publication job, including its experience and reputation for excellence.

2. The manner in which these materials will complement the publisher's portfolio of products.

3. The caliber of the staff to be assigned to the publication effort.

4. The amount of money the publisher is willing to commit to the revision and publication effort.

5. The proposed format of the final package of materials.

6. The time frame for accomplishing publication.

7. The promotion and sales plan submitted by the publisher.

8. The proposed royalty schedule.

9. Agreement to support a part of the cost of the field test and revision of the teacher's guides, as an advance against earned royalties (see Appendix B).

SUBMISSION OF PROPOSALS

All proposals are to be submitted in duplicate and sent soon enough to be received 45 days after the date of this RFP. Proposals are to be sent to:

Professor Morris H. Shamos
Director of COPES, New York University
4 Washington Place, Room 509
New York, New York 10003

It is expected that a publisher selection will be made within 30 days after the deadline for the receipt of proposals.

enc: Tables of Contents through Grade 4
Summary of Plan for Field Testing

APPENDIX A
TABLES OF CONTENTS

KINDERGARTEN

IDENTIFYING THINGS AROUND US

Some Things Around Us
Creating an Environment for Living Things
Arranging Objects into Groups
How to Show that Objects Belong to a Group

DESCRIBING OBJECTS

How is it Different?
Grouping Materials as Solids or Liquids
Grouping by Properties
What are its Parts?
Small Parts

MAKING COMPARISONS

Comparing Dimensions
Comparing Weights
Comparing Number of Objects in Groups

CHANGES

Changes in Living Things
Sensing Motion
Pushing and Pulling
Melting
Absorption of Water
Cooking Foods

GRADE 1

PROPERTIES

- Reviewing Properties
- Solids, Liquids and Gases
- Sizes, Colors and Shapes
- Different Ways of Grouping Objects
- Taste as a Property
- Odor as a Property
- Germination, a Property of Most Seeds

MEASUREMENTS

- Ordering Objects in Terms of Size
- Measuring and Estimating Amounts
- Combining Volumes
- Equivalent Volumes of Liquids and Pourable Solids in Different Shaped Containers
- Extending the Concept of Conservation of Material
- Measuring Lengths
- Warm and Cold/Using a Thermometer

INTERACTIONS

- Changes in Environments
- Interacting with Water
- Making Solutions
- Interaction Between Magnets
- Experiencing Gravitational Force
- Adding and Removing Heat Energy from Substances

VARIABILITY

- Variations in Motor Skills
- Variations in Physical Characteristics
- Variations in Events
- Variations in Germination Time

GRADE 2

WHOLE, PARTS AND PATTERNS

Seed and Plant Patterns
Sounds and Instruments
Patterns of Sound
Patterns of Taste
Patterns in a Magnetic Field
Patterns of Color

MEASUREMENTS, CHANGES, AND PATTERNS

How Long is It?
How Much Does It Weigh?
Measuring Volume
Keeping Track of Matter
Time to Swing

PATTERNS AND PREDICTING

Using Measurement to Show a Pattern
Prediction and Temperature Change
Patterns in the Classroom
Figuring it Out

GRADE 3

THE PARTS OF WHOLES

Mosaics
Sieving Soil
A Very Fine Sieve
In and Out of Solutions
Where Did the Green Go?

BALANCED AND UNBALANCED FORCES

Forces: Pushes or Pulls
Stretching Rubber Bands
Which Way Will the Paper Clip Move?
Measuring Gravitational Force
Weight: A Measure of Gravitational Force

AVERAGING AND SAMPLING

A Fair Share of Peanuts
A Third Grader's Family
With the Greatest of e's

INTERACTIONS IN ELECTRICAL CIRCUITS

Finding Out About Circuits
Putting Different Materials in a Circuit
Putting More Batteries in a Circuit
Evidence of Battery Interactions
Heat Energy From Batteries and Wires

HEAT ENERGY AND WATER

The Celsius Thermometer
Increasing the Temperature of Water
What Factors Affect a Temperature Increase?
What Else Affects a Temperature Increase?

INVESTIGATING STARCH

Two Properties of Starch
Testing to Be Sure
The Interaction of Starch and Water with Heat
Energy
Parts of Wholes

GRADE 4

CONSERVATION OF MATTER

- The Weight of Melting Ice
- Loss of Weight in an Open System
- Increase of Weight in an Open System
- New Substance, Different Weight?
- "Drying" Apples
- A Bread Mold System

THE WATER MIX

- Water: A Source of Heat Energy
- Inventing the Heat Energy Unit
- Volume and Heat Energy
- Making Mixes: Water at the Same Temperature
- Making Mixes: Water at Different Temperatures
- Using the h.e.u. to Make Predictions
- A Return to Melting Ice

HEAT ENERGY TRANSFER

- Locating Points: Coordinates
- A First Look at A System
- Quantifying the Results
- Where From and Where To?

MOLECULAR SIEVING

- Taking the Red Out of Red Cabbage
- Constructing a Model of a Red Cabbage Leaf
- Molecules of Different Sizes
- Some Final Observations and Inferences

CHANGE OF STATE

- "Disappearing" Heat Energy Units
- Thinking About Solids and Liquids
- Using the Model
- In and Out of the Melt
- Molecules in a Gas
- In and Out of the Gas

USING FREQUENCY DISTRIBUTIONS

- How Many Seeds in a Pod?
- Introducing the Histogram
- How Old are Fourth Graders?
- How Long is a Fourth Grader's Finger?
- Where It Stops, Nobody Knows
- Return of the Pods

APPENDIX B

Summary of Plan for Field Testing COPES Materials

Professor Philip R. Merrifield, who directs the development of evaluative materials for COPES, has worked out an unusually unique design for field testing COPES. Among other things, the design will make it possible to determine the various conditions within a school under which COPES is most successful. We consider this to be a unique feature of our field testing plan, since such a critical decision was not used in evaluating other elementary science projects.

Another unique feature of our plan is that the local schools which are selected as cooperating schools, will assume major responsibility for the cost of the testing. We are greatly encouraged by the number of positive responses we have thus far obtained from schools to this rather unconventional arrangement.

As we presently view it, the field testing phase of COPES will take two years. The first year will be given over to the following tasks:

1. Producing the evaluative instruments to be used in field testing,
2. Producing special materials for local science coordinators or supervisors,
3. Producing special materials for those who will do the inservice work with teachers (to supplement the Teacher's Guides), and
4. Conducting local inservice programs for cooperating teachers.

During the second year, the materials will be field tested in the schools.. The Merrifield design makes it possible to test a seven-year (K-6) science program in one year. Analysis of the test results will lead to final revisions of the present preliminary editions of the Teacher's Guides, resulting in a commercially produced first edition of the Guides. We see the commercial version of COPES as consisting of a package containing the following items:

1. Teacher's Guides,

2. Pupil workbooks and assessment materials,
3. Evaluation materials for schools to use in obtaining an overall assessment of achievement of children in the COPES curriculum,
4. And possibly, Auto-Tutorial materials for:
 - a. science coordinators and/or supervisors,
 - b. those responsible for the inservice preparation of teaching, and
 - c. teachers responsible for teaching COPES at the different grade levels.

The estimated cost for operating the COPES Headquarters unit for two years at New York University to accomplish the above is \$350,000. The cost to each local cooperating school will vary, depending upon local circumstances, from as little as \$2,000 to as much as \$15,000 for the two-year period. At least ten schools will be involved in the field test, but this may be increased in multiples of five.

To be eligible for consideration, a publishing company must be willing to support the cost of maintaining the Headquarters unit of COPES for two years (approximately \$350,000), this sum to be considered as an advance against earned royalties, as well as the cost of revising the materials, also as an advance against royalties. Both the University and USOE have agreed to waive their shares of royalties up to the cost of field testing. Local cooperating schools will be expected to cover their own costs of field testing, except that the publisher will be expected to provide the materials to be field tested. It is to be understood that the company selected as the publisher would then have first option to produce and distribute the above under contract with the developers of COPES, and by arrangement with the United States Office of Education.

APPENDIX H
REPORT ON EXPERIMENTAL COLLEGE SCIENCE COURSE
BASED UPON THE CONCEPTUAL SCHEME APPROACH

Paul J. Gans

The course "Basic Concepts of Chemistry", A25.0003, was offered for the first time in the spring semester of the academic year 1970-71. The course was initiated by Prof. A.I. Kosak, Head of the All-University Department of Chemistry, at the request of Prof. J. Darrell Barnard, Head of the Division of Science and Mathematics Education in the School of Education. The course was taught by Prof. Paul J. Gans of the Department of Chemistry. Initial planning of the course details was done by Prof. Barnard, Dr. Janice Cutler, Prof. Edward McNelis, and Prof. Gans. Final detailed planning was the responsibility of Prof. Gans, who enjoyed the able and experienced counsel of Dr. Cutler throughout both the planning stage and the actual presentation of the course.

From the start the course was designed to be primarily relevant to students contemplating a career in elementary education, but was not in any way limited to such students. It has become a commonplace that students whose educational background includes little or no physical science suffer from a general dislike and distrust of science courses. In particular they are assumed to feel that the physical sciences are difficult to understand, filled with detail unimportant to their lives or career objectives, and esoteric in concept and content. Nonetheless, many of these students, in particular those majoring in elementary education, say that theoretical in

situations where their unconscious attitudes influence other students during their formative years. Thus a dislike and distrust of science propagates, to the detriment of both the individual and science.

Clearly, no single course or educational experience can strongly affect public attitudes or fears. However, it must be recognized that some of these attitudes and fears are the direct outgrowth of course work in science that fails to educate. Thus the course "Basic Concepts in Chemistry" was designed from the start to have a dual purpose. It would not only be a content course, but it would also attempt to develop positive attitudes toward science, scientists, and the scientific method. This last objective was not to be done directly, but rather by structuring the course material so that the subject matter and methodology of at least a small part of one science could be made clear in terms understandable to the students taking the course.

As for the actual content of the course, it was decided to try a single concept approach. This has not been the normal technique in introductory courses in chemistry. Traditionally the material covered in such a course has been disjoint. Indeed it may be suspected that the disjoint nature of introductory courses in the past has produced a conflict within the student, who, being told of the unity of science, and being unable to perceive it in his course, inevitably comes to the conclusion that either the complexity of science is beyond him or that scientists think differently than human beings.

Because of success in using a similar approach in courses developed for teacher in-service training for the Copas project, Dr. Cutler was able to argue convincingly for a single concept approach based upon the role of energy in chemistry. This was adopted, and in large measure credit for the success of the course must go to her. It was realized that a one semester course could not cover a great deal of material, but that concentration upon energy as a unifying idea would provide an entry into several fairly complicated topics. Further, it quickly became apparent that no existing textbook would meet the needs of the course. In spite of the fact that a textbook is often psychologically important to a student, it was felt that the importance of the course concept outweighed the lack of text. Thus no text was used; instead the lectures were supplemented by sets of mimeographed notes handed out frequently during the term.

With energy as the unifying concept for the course, an outline of topics was set up. This outline, in class schedule form, is reproduced as page 3 of the notes. It can be seen from the outline that the initial topics presented was to be the meaning of temperature and its relation to thermal energy. Topics then progressed in a logical manner building to more and more complex ideas. It was expected that a discussion of energy in its various guises would occupy the first two-thirds of the course. The last third would be devoted to more specialized chemical topics, further developing the material of the first two-thirds of the course.

In summary then, the preplanning of the course produced the following major points: (1) The expected student body would have relatively little technical background and a general resistance to the idea of science as a comprehensible and interesting body of knowledge. (2) The purpose of the course would be twofold - to teach a unified body of material that would range in depth from the simple to the complex, and to do so in such a way as to counteract expected preconceived student notions about science. (3) The unifying concept chosen was energy. (4) No text would be used, but mimeographed notes would be provided by the instructor.

In execution the course proved educational to both student and teacher. The original topical outline was followed through the middle of the term, and then modified (not unexpectedly) in the light of experience and rate of progress of the course. One major modification was made the first day in reaction to preliminary informal conversation with the students enrolled in the course. The actual enrollment proved to be sixteen, with three students from Washington Square College and the remainder from the School of Education. A large majority were interested in careers in education. After the usual introductory material on the first day, an informal discussion was begun on attitudes toward science. The discussion lasted for several class periods, it being felt that the issue, having been raised, should be met head on. The first chapter of the notes was produced as a result and made available for the second day of class. The notes, as is apparent on examination, were meant to be a provocative guide rather than a summary of what was actually said. They do give some indication of the

most of the discussion. One could not avoid the conclusion that, if anything, the students' fear and misunderstanding of science was greater than expected. Attitudes ranged from a totally romantic view of science as a dedicated server of humanity, idealized to the point of total dehumanization, to almost complete cynicism as to the worth of science and the sanity of the scientist. The purpose of science was variously, if extremely stated as "improving the world" and "providing employment to unemployables". The discussion was full and frank, and hopefully provided some new thoughts to the students. No attempt was made to argue students into a new viewpoint, it being felt that that was the purpose of the course itself. Interestingly, the teacher was either not thought to be a scientist, or else was considered completely atypical, merely because he was willing to have this kind of discussion in class. After several sessions, a summary sheet (page I-3) was produced that presented a middle synthesis of the class opinion.

The nature of the course as actually given can be inferred from the lecture notes. These were generally distributed before the material was actually discussed. Early topics were approached by an appeal to common experience and constant reference was made to everyday situations. Progress initially was intentionally slow with both constant repetition and drill on fundamental concepts. Questions and discussion were encouraged from the class, though a well-timed intervention was used. The primary pedagogical tactic employed at this stage was to emphasize that the material was not being studied, but was being used to explain the world around them. The material was being prepared for use in the future.

frequently pointed out that this is a primary function of science.

As the term progressed and the material became less 'common knowledge', the character of the notes changed. More explanatory material was given. However, since the notes were still given out prior to class discussion they did not always touch the main points of difficulty found by the student. Indeed the character of the notes became just that, notes, and not textual material. Errors occurred that were corrected in class, and in many cases better verbal explanations given. The basic tactic here was to blend what everyday experience there was with both historical and philosophic background; with emphasis of the accretion of ideas by small, simple steps. Class reaction was very good, and much faster progress was made than had been anticipated.

The faster progress coupled with certain deficiencies in the original plan prompted a major departure from the original topical schedule by the middle of the term. Much stress had been put on the use of science as a tool to understand complex situations in terms of simpler ones. After the introduction of the kinetic-molecular theory it was decided to use the behavior of ideal gases as a case study. The notion of pressure was introduced and then the class encouraged to deduce the properties of ideal gases simply on the basis of kinetic theory and elastic collisions between molecules. This was not only successful, but highly pleasing to the class who now seemed to feel some confidence in their deductive and reasoning abilities. The point was made that this topic, in perspective, was science; that, after ideas

and insights can and are developed from simple considerations of simple ideas. More importantly the class itself suggested that had they been told of the contents of chapter VII on the first day of class, they would have had all of their worst fears confirmed.

After ideal gases, the sequence of topics more or less returned to that originally planned. However, again toward the end of the course a second major departure was undertaken, this time at the instigation of the class itself. It was decided to undertake a survey of the periodic chart with emphasis on the group properties of the elements. The class was more sanguine of the success of such a procedure than the instructor, and as a result the notes reflect only part of the material discussed in class. However, the class was more right than wrong, and the topic must be considered a success.

The preplanned material for the course was exhausted before the end of the term, the students showing that the preplanned pace was too slow. As a result several topics were added at the end, one, a very cursory introduction to organic structural chemistry, was included in the notes; the other, a set of lectures on proteins and DNA was not. This last topic was omitted simply because there was insufficient lead time to prepare proper notes.

In reviewing the course both the class and the instructor felt that it was a success. During the term there was constant discussion of science and its meaning and role. Students from many different backgrounds admitted a definite change in attitude, and while still not convinced of the value of science, they were at least more open to its merits.

was appreciated. Perhaps the best proof of this is the fact that more material was indeed covered than had been expected prior to the start of the course.

Difficulties also emerged. Apart from some that were purely physical (unsuitable room, mechanical difficulties associated with non-educational events taking place on campus during the term, etc.) it became clear that the laboratory work needs to be much improved. In general laboratory experiments were chosen to flesh out lecture material and to integrate with it. This must be expanded upon for the future. However, the students, once their fear of laboratories and chemicals was overcome, also wanted more manipulative and synthetic experiments for the lab, even if these did not exactly tie in with the lecture topics. Since a better appreciation can now be had for the pace and quantity of material that can be covered in one term, it is possible to, in fact, both better integrate the lab and provide more interesting experiments.

It also became clear that more audiovisual material was wanted. Some was used during the term. Finding more will prove somewhat difficult but should not be impossible. The difficulty arises from the fact that, instead of superficially hopping from topic to topic, we had in fact gone quite deeply into some areas - but that as a result some traditional peripheral ideas had been slighted in favor of depth in others. Most traditional audiovisual material presupposes just this scatter approach gotten away from in this course. Hence finding good material was, and will not be, easy.

Further, it is absolutely clear that this course can only work if it is highly interactive between a class and instructor; and thus hence the class size must be severely limited. Thirty students is probably the maximum that can be handled under the present organization. Moreover, it is also clear that this course cannot be taught as a traditional science course is taught. The instructor cannot rely on revealed truth to hold the class interest. Questions ranged from wanting to know if Nobel Prize scientists have abnormal personalities to why fireflies light up. And these questions have got to be discussed. Further, the class in developing freedom of expression necessary to break down the psychic bars against science, tends to ramble. These wide ranging excursions into questions they have had unanswered since early childhood have to be handled in such a way as to develop the students ability to develop his own answers. There can be no rules on how to do this, the interaction of a particular class with a particular instructor is crucial.

In conclusion it can be judged, admittedly subjectively, that the course met its objectives. It can cover more material. It should be continued. Speaking personally, it has been quite an educational experience for me, and involved a good deal more work than anticipated. Perhaps that is why I found it so enjoyable.